ENVIRONMENTAL CONDITIONS AND BIOLOGICAL CONTROL OF THE BEET ARMYWORM

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Abstract

The beet armyworm has become a widespread cotton pest, causing great damage in some areas. Many questions relative to the occurrence of this pest and the factors regulating its population dynamics remain unanswered. At least four strongly interacting circumstances contribute to beet armyworm outbreaks: (1) the presence of beet armyworm populations, (2) suitable conditions in the field and in the quality of the plants in the field for development and survival of the beet armyworm, (3) appropriate weather conditions, and (4) insecticide history of the field or region. Further work is needed in each of these areas to define the levels and components of the several factors that create or detract from outbreaks. It is clear, however, that the beet armyworm is an induced pest, and that efforts to conserve the natural enemies of this pest will result in at least partial, if not complete, control.

Introduction

The beet armyworm, Spodoptera exigua (Hübner), has recently become a widespread pest of cotton in the United States from Texas eastward. This pest has been particularly destructive in portions of the Southeast for the pest 8 years, and in 1995 was a serious problem in south Texas. Where did this menace come from?

The species is native to the tropical and temperate zones of Asia and Africa (Kawana 1993), but was first collected in the U.S. in California and Oregon in 1876 (Harvey 1876). From here it spread rapidly across the country: in 1899, it was observed feeding on sugar beets in Colorado; in 1904 damaging cotton in Texas; damaging sugar beets in Kansas in 1911; feeding on corn in Mississippi in 1931; and attacking asparagus fern in Florida in 1932 (Wilson 1934). After establishing in the respective states, it historically caused localized problems on various crops, but was rarely a serious pest on a regular basis or on a large scale. In recent years it has become an explosive and devastating pest of cotton in regions of the Cotton Belt, extending from Texas eastward. What makes this pest so destructive?

General Biology of the Beet Armyworm

The beet armyworm possesses several traits that predispose it to be an effective pest species. First, it has a broad host range. It has been recorded feeding on over 90 plant species in North America, many of which are crop plants (Pearson 1982). As one Entomologist put it, it restricts its feeding to "only green plants". The ability to feed on a wide range of host plants allows the insect population to build over widely-distributed crop and non-crop areas (much of it probably untreated with insecticides) and move into grower fields in large numbers. Second, the beet armyworm is highly mobile. Although it apparently only overwinters in the southern United States, it is capable of invading most states during the summer months (Mitchell 1979). French (1969) demonstrated that adult beet armyworms in North Africa were capable of immigrating to the British Isles on wind currents in only a few days. This capacity to move long distances makes it more difficult to pinpoint sources of beet armyworm populations and adds additional unpredictability to the when and where of beet armyworm outbreaks. A third feature that contributes to the pest status of this insect is its capacity to increase. This is a result of the insect's relatively short developmental time (as brief as 17 days from egg to adult in mid-summer temperatures; Ali & Gaylor 1991) and high reproductive capacity (ranging from 500 to more than 1700 eggs per female; Wilson 1934, Hogg & Gutierrez 1980, Chu & Wu 1992). Finally, beet armyworms show considerable tolerance to most insecticides (e.g., Cobb & Bass 1975, Brewer & Trumble 1989, Wolfenbarger & Brewer 1993), which varies among regions (Cobb & Bass 1975, Chandler & Ruberson 1994).

Overall, the beet armyworm is a highly resilient and adaptable insect that may recently have adapted to cotton as a primary host plant. Because of the recent magnitude and persistence of the beet armyworm problem in cotton, it is quite probable that problems with beet armyworms will continue to grow, or at least persist, in the future. As a result, it is valuable to pause and reflect on what is known (and what is not known) about environmental factors that contribute to the pest or non-pest status of this insect. Outbreaks of the beet armyworms are most likely related to the interactions of four factors: (1) the presence of beet armyworms, (2) suitable conditions in the field and in the quality of the plants, (3) appropriate weather conditions, and (4) insecticide history of the field and region.

Environmental Factors and Beet Armyworms

A substantial amount of anecdotal information is available concerning the factors contributing to beet armyworm outbreaks in cotton, some of it supported by excellent observations. However, much remains unclear and future research in this area is needed. This presentation will consider various aspects of the relationship between beet armyworm populations and environmental factors, and will point out areas where further research is needed. It will consider each of the four components of a beet armyworm outbreak noted above, then conclude with brief discussion of the role of natural enemies in controlliing beet armyworms.

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Sources of Beet Armyworm Populations

Beet armyworm populations are known to overwinter in some states (California, Florida, and Texas), but there is reasonable evidence to suggest that they are capable of, and likely are, overwintering in the northern Gulf states as well, at least during winters that do not have extreme cold (Ruberson et al. 1994a, Hendricks et al. 1995). Although the beet armyworm is incapable of a true diapause that would allow it to hibernate through the winter in temperate regions, as is the case for many other insects, it can nevertheless slow its development and survive cold periods quite well. The availability of host plant material during the cold winter months may be a greater limiting factor for beet armyworms in the northern Gulf states than is their physiological ability to cope with cold temperatures. The problem of availability of winter plants for consumption may be resolved, in part, by the expanded vegetable acreage in southern Georgia and Alabama. It is certainly possible that beet armyworms are able to overwinter further north than previously believed, at least during mild winters.

Having overwintering beet armyworm populations locally or nearby may increase the chances for localized problems, which may, in turn, contribute to regional problems if conditions are suitable. This aspect of beet armyworm biology warrants further investigation. Particular areas, such as the vicinity of Yazoo City, Mississippi, and areas of Dooly County, Georgia, have persistent populations year-to-year, and may have resident year-round beet armyworm populations. In Mississippi, Hendricks et al. (1995) found moths in traps in April that exhibited little damage, and suggested that they may be from local overwintered populations.

Weather and the Beet Armyworm

Weather conditions suitable to beet armyworm movement, reproduction, development, and survival are certainly critical to the development of beet armyworm outbreaks, but what are the necessary conditions? The few ideas concerning weather and beet armyworm outbreaks are nearly all anecdotal, but have been verified consistently enough to suggest that they have more than a kernel of truth. Nevertheless, the mechanisms for the observed results are obscure, and the circumstances surrounding the observations are not always sufficiently clear to permit one to make accurate predictions based on these observations.

Many have observed that beet armyworm outbreaks often occur in hot, dry years, and, conversely, the problems are nearly nonexistent in particuarly wet years. For example, beet armyworms were a problem on cotton in parts of the southeastern United States in 1977, when a severe drought occurred in this region (Mitchell 1979). Similarly, the beet armyworm problems in Georgia during the Boll Weevil Eradication Program were most acute in 1988 and 1990, two particularly dry years. In contrast, beet armyworms are rarely a problem in wet years. For example, beet armyworm outbreaks were essentially nonexistent in Georgia during 1994, which was unusually wet, even in fields where heavy insecticide use should have easily induced outbreaks. These observations coincide with results from Africa with the African Armyworm, Spodoptera exempta, a serious pest of grass crops and a close relative of the beet armyworm. Tucker (1994) found that outbreaks of this armyworm were greatest in years with intermittent rainfall, separated by prolonged dry periods, whereas populations were lowest in years with high (above average) and consistent rainfall. These patterns were not absolute, however, as is probably the case in the United States with the beet armyworm.

What mechanisms might be the basis for these observations? First, as noted above, beet armyworm moths can migrate long distances. It is possible that the large-scale weather patterns responsible for inducing the hot, dry weather are conducive to movement of the moths, so that their dispersal ability is enhanced. Tucker (1994), however, found that African armyworm moth flights usually intensified immediately after a storm front had brought rain through an area, suggesting that the moths were carried in the moving front. Second, hot and dry weather may influence the microhabitat within the fields, making them better habitats for the beet armyworm. This may be due to concentrations of nutrients in the plants (see below), reductions in natural enemy populations (which can occur under extreme conditions of heat and drought), increased attractiveness of the plants for ovipositing moths, or other factors. Third, there are several pathogens of beet armyworms (fungi and viruses) that can locally destroy populations of this insect under wet conditions. Dry conditions may prevent them from functioning, increasing survival of larvae. Fourth, heavy rains tend to dislodge beet armyworm larvae from the plants and drown them. Persistent rainy periods may wash large numbers of eggs and/or larvae from the plants. Rain also reduces the flight activity of the adults. These areas require study to clarify the observations and establish environmental thresholds or indicators that could be used to anticipate beet armyworm problems. One issue for which no good answer currently exists is: How hot is hot and how dry is dry to trigger beet armyworm outbreaks?

Condition of the Plant/Field and the Beet Armyworm

Several factors in a field and a plant probably contribute to the occurrence of beet armyworms in the field. For example, it has often been observed that beet armyworm problems tend to be worse in "skippy" stands of cotton. In fact, student workers collecting larvae for me learned quite rapidly, and without any suggestion from me, that the best places to search for larvae in a cotton field were in areas where the stand was incomplete or where the plants were stunted relative to the others. In fields, therefore, where seedling disease has had considerable impact, beet armyworm problems may be more likely. The basis for this phenomenon is unclear. Ovipositing females may select open sections of the field, or larvae may survive better in those areas than in areas where the stand is solid.

Sandy soils have also been considered to be more amenable to beet armyworm outbreaks than are other soil types (Smith 1989). We have made similar observations in Georgia, but the mechanism is not clear, nor is this generalization consistently accurate. Soil properties could exert a variety of effects on beet armyworms, both directly (e.g., light reflectance, heat retention or emission) and indirectly (through the plant). Indirect effects might be more pronounced in dry years, when moisture and nutrients are more readily lost in sandy soils, leading to plant stress. Plant stress may affect the behavior of beet armyworms toward the plant, as will be discussed below.

The cotton plant itself certainly influences the occurrence of beet armyworms. Although several reports have claimed that some cotton varieties are more likely to be attacked by beet armyworms than are others, there is no evidence to support these claims. Plants that appear to be stressed (e.g., wilted, stunted, or yellowing) tend to be more prone to attack than are healthier plants (Smith 1989), but when infestations become heavy no such tendency is evident. The African armyworm was found to be more damaging when plants possessed high levels of nitrogen than when such was not the case (Janssen 1993). The additional nitrogen was also found to benefit the developing larvae. Could the same occur with the beet armyworm?

Various factors contribute to plant stress and quality (including moisture levels, light, disease, and nutrition), many of which are related to weather conditions. Here again, the mechanisms for any preference with regard to plant quality are unknown. It is possible that ovipositing females are attracted to the color difference of the stressed plants, or that volatile chemicals released by the stressed plants are more attractive to ovipositing females. Alternatively, larvae may survive and/or develop better on stressed plants than on flourishing ones. Different host plants have been shown to affect the development, size, longevity, and reproductive capacity of the beet armyworm (Ismail et al. 1976); therefore, plant quality may also affect the survival and reproduction of these insects in the field. In addition, certain natural enemies of the beet armyworm (such as the wasp Cotesia marginiventris) are attracted to chemicals released by cotton plants being attacked by beet armyworms. Stressed plants may have a lower capacity to release volatiles and attract natural enemies to the beet armyworms than do healthy plants, thereby making stressed plants "safer" hosts for the larvae.

Insecticide Use and the Beet Armyworm

It has become increasingly clear that insecticides can trigger outbreaks of the beet armyworm in areas where armyworm populations are available and other conditions are suitable. Eveleens et al. (1972) were able to induce beet armyworm outbreaks in cotton in California using the organophosphate dimethoate. Similarly, many areas that have participated in the Boll Weevil Eradication Program, with its widespread use of organophosphate insecticides, have also experienced dramatic beet armyworm outbreaks. This was particularly apparent this year in Texas. These insecticide-induced outbreaks appear to be related to impairment of the natural enemies that otherwise appear highly capable of holding the beet armyworm populations in check (Ruberson et al. 1994b).

Biological Control of the Beet Armyworm

The beet armyworm is attacked by a large complex of natural enemies, including predators, parasites, and pathogens, across the U.S. Cotton Belt (Ruberson et al. 1994b). As noted above, Eveleens et al. (1972) induced beet armyworm outbreaks by applying an organophosphate insecticide to cotton. They further studied rates of beet armyworm loss due to natural enemies in treated and untreated cotton and found that the natural enemies and their impact were greatly reduced in the insecticide-treated area. Similar experiences can be repeated from Georgia and other areas. In Georgia, severe beet armyworm outbreaks accompanied the repeated applications of organophosphate insecticides during the active phase of the Boll Weevil Eradication Program, but these problems have subsided with the passing of the Eradication Program into a containment phase. Nevertheless, the potential for problems on a local scale persists. Growers who use organophosphate materials, or repeated applications of pyrethroids, can place themselves at risk for beet armyworm problems. Studies conducted in Georgia have demonstrated that beet armyworm larvae can suffer very high levels of mortality (generally in excess of 98%) due to natural enemy activity (Ruberson et al. 1993, 1994a, 1994b). Similar results have been obtained from California (Hogg & Gutierrez 1980). In high beet armyworm-risk areas, therefore, efforts should be made to conserve natural enemies through use of selective insecticides, or use of reduced rates of broad-spectrum materials. Continued studies are needed to determine which natural enemies are most important, and which insecticides can be used safely with these key beneficial species.

In addition, further work is needed to understand the dynamics of insecticide applications on a regional scale. How do such applications affect natural enemy populations and their colonization of fields? Can refugia for natural enemies be retained in such programs? Until we begin to obtain answers to these questions, we will continue to struggle with secondary pests, such as the beet armyworm, as we tackle area-wide management programs, such as the Boll Weevil Eradication Program.

Conclusions

Several interacting circumstances contribute to outbreaks of the beet armyworm: (1) the presence of beet armyworms,

(2) suitable conditions in the field and in the quality of the host plants for development and survival of the armyworms, (3) appropriate weather conditions, and (4) insecticide history in the field or region. The relative contributions of these circumstances are not presently understood, but future work should address those factors that influence each of these circumstances so that ultimately the outcome can be manipulated for the benefit of the cotton growers.

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