THE ROLE OF BIOLOGICAL CONTROL IN *LYGUS* SPP. MANAGEMENT

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Abstract

Lygus spp. are attacked by a variety of predators, parasites, and pathogens, but the impact of this natural enemy complex on Lygus populations is not well known. Several species of exotic parasites have been introduced into the United States, one of which is now established in a limited region of the northeastern U.S. Several studies indicate that some native predators and parasites can inflict high mortality on Lygus populations; however, efficacy of these natural enemies appears to vary among the bugs' host plants, with crop systems experiencing some of the poorest biological control. The fungal pathogen *Beauveria bassiana* may become a valuable tool in the future for managing early-season populations of *Lygus* spp. in crop systems. More information is needed on the role of natural enemies in the population dynamics of *Lygus* spp., in both crop and natural systems. This information may help us develop programs using natural enemies to target and suppress Lygus populations over large areas, and before they enter the cotton system. Continuing efforts also should be directed toward importing exotic, effective natural enemies that can provide permanent population suppression.

Introduction

Lygus spp. comprise a serious pest problem for a number of crops, including cotton. Management of *Lygus* bugs is often problematic because of the high mobility, broad host range, cryptic damage, and poorly understood population dynamics of these species. In cotton, control decisions are further complicated by often inadequate sampling procedures and difficulty in defining thresholds (see Layton 1995 for review of thresholds across the Cotton Belt).

Control options for *Lygus* spp. are quite limited at present, with chemical measures being the dominant control means. Nevertheless, insecticides used against *Lygus* spp. are broad spectrum materials that can lead to serious disruptions of beneficial species in the cotton system, particularly early in the season when natural enemy populations are building in the crop. These disruptions can lead to increased use of insecticides during the remainder of the season, increasing grower costs and environmental risks. Biological control of *Lygus* spp. is not well defined at present, and as a result has little to offer growers at its present level of sophistication. In the future, however, natural enemies may offer additional management options that are effective.

This paper addresses the current status of biological control of *Lygus* spp. in the Cotton Belt. For the purposes of this paper, only two *Lygus* spp. will be considered: *Lygus hesperus* and *Lygus lineolaris*. These two species comprise the majority of the *Lygus* spp. present in U.S. cotton. *Lygus hesperus* dominates in the western United States. *Lygus lineolaris*, in contrast, is found throughout the United States and Canada, although it is a more serious cotton problem in the eastern half of the United States in the western half. Both species are native to the Nearctic region and occur in many habitats and attack many host plants in addition to cotton. The natural enemies appear to be comparable or shared for both *Lygus* species; thus, in this presentation there will be little attempt to distinguish between natural enemies of the two.

Natural Enemies of *Lygus* Spp.

Lygus spp. are attacked by a variety of natural enemies, including predators, parasites, and pathogens (Coulson 1987, Schuster 1987, King et al. 1996; Table 1). They are susceptible to natural enemies at all life stages, from egg to adult, although levels of mortality vary among life stages. The natural enemies of *Lygus* spp. are briefly discussed below.

Parasites of *Lygus* spp. belong to the insect orders Hymenoptera (ants, bees, and wasps) and Diptera (flies). The most common parasites are hymenopteran species (Table 1). Eggs are reportedly attacked by two species of parasites (both of the hymenopteran family Mymaridae): *Anaphes iole* and *Polynema pratensiphagum*. Of these two, *A. iole* is common in the southern United States, while *P. pratensiphagum* occurs in Canada. Most studies of *A. iole* have been conducted in the western United States, but it is reported to occur in the eastern portion of the Cotton Belt, as well (Scales 1973). *A. iole* attacks at least several species of mirids, and is capable of parasitizing eggs of *Nabis* spp., although this is probably quite rare (Jackson and Graham 1983). *Lygus* spp. insert their eggs into plant tissue, in cotton most egg deposition occurs in the upper third of the plants, at the juncture of the stem and the petiole (Graham et al. 1986). Eggs are located by *A. iole*, apparently in response to cues left behind by the ovipositing female Lygus bug in the scar where the egg is inserted (Conti et al. 1997). The parasite destroys the bug embryo before the egg hatches, and emerges after 3-4 weeks of development (Jackson 1987). Parasitism is most successful in young eggs (1-4 days old), but parasites can still emerge from eggs parasitized shortly before hatch, although with less frequency (Stoner and Surber 1969). *A. iole* has been found attacking *Lygus* spp. eggs in a variety of crop systems, but its efficacy in cotton appears to be reduced relative to that observed in other crops (Graham et al. 1986). In some systems, parasitism by *A. iole* is quite high. For example, in alfalfa, parasitism rates have been reported to range from 0 to 53% (Graham et al. 1986). Few studies have been conducted in cotton, but in Arizona, parasitism rates in

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cotton tended to be lower than those observed in wild host plants (Graham et al. 1986). Considerable effort has been expended in developing rearing methods for *A. iole* so that inundative releases could be undertaken (e.g., Jones and Jackson 1990), and there may be opportunities for using this parasite for managing *Lygus* spp. (see below).

Evaluation of parasitism for nymphal and adult *Lygus* spp. is often difficult, because of typical high mortality among bugs transferred to the laboratory (Hedlund & Coutinot 1983, Bilewicz-Pawińska & Varis 1985). This problem can be circumvented by dissecting the bugs shortly after capture, but identification of the immature parasites is often impossible. A recently-developed method, using parasite DNA may provide greater opportunities to appropriately attribute parasitism to proper parasite species (Tilmon et al. 1997). Despite the difficulties of assessment, the braconid wasp *Leiophron uniformis* has been reared often from *Lygus* spp. nymphs and adults (Graham et al. 1986), and occurs throughout the United States. Although multivoltine, *L. uniformis* typically parasitizes low levels of *Lygus* spp. throughout the season [e.g., maximum of 19% of adults and 11% of nymphs in alfalfa in California (Clancy & Pierce 1966)]. An exotic *Leiophron* sp. was imported into the United States from Kenya in 1985, but no establishment has been recorded (King et al. 1996).

Peristenus pallipes and *Peristenus pseudopallipes* are univoltine, native braconid wasps that attack nymphs of *Lygus* spp. and emerge from either the late nymphal or adult stages (Lim & Stewart 1976). *P. pallipes* appears to be prevalent from Texas eastward, while *P. pseudopallipes* has a northern distribution, primarily in Canada. In alfalfa, parasitism of bugs by *P. pallipes* varies considerably (e.g., Clancy & Pierce 1966), but rarely exceeds 40%, and is usually considerably lower. Host plant also influences the effectiveness of *P. pallipes*. Streams et al. (1968) reported that parasitism of *L. lineolaris* nymphs in Connecticut ranged from 0% on evening primrose to over 40% on fleabane (*Erigeron* spp.). Similarly, parasitism by *P. pallipes* was variable on non-crop plants in Mississippi and Arkansas (Scales 1973). Efficacy of *P. pallipes* is likely limited by the univoltine life history of the parasite -- with only a single generation each year, the parasite is unable to respond reproductively to Lygus populations as they increase from generation to generation during the season.

Other species of *Peristenus* have been imported, primarily from Europe, for biological control of Lygus spp. (see Table 1, exotic source). These importations have not been overly successful to date (Coulson 1987, Jackson et al. 1995). Only a single introduced species, *Peristenus digoneutis*, has established, and that has been in the vicinity of one of its release points -- New Jersey and New York (Day 1996).

Several species of flies, all of which belong to the tachinid genus *Phasia*, have been reared from *Lygus* spp. (Table 1). None of the flies, however, parasitizes significant numbers of bugs (Clancy & Pierce 1966, Day 1995), and likely contribute little to suppression of their populations.

Predators of *Lygus* spp. are not well studied (King et al. 1996), most likely because of the difficulties typically encountered when studying arthropod predation (Jervis and Kidd 1996). A variety of predators have been reported to feed on Lygus adults, nymphs, and/or eggs in the laboratory or field (Table 1); however, the impact of predators on *Lygus* spp. populations are unknown. In field cage studies, Leigh and Gonzalez (1976) found that the natural predator complex reduced nymphal populations of *Lygus hesperus* 53-76% relative to controls from which predators had been eliminated with insecticides. They observed that 99% of the predators present in the cages were *Geocoris pallens*. In small-cage tests, *Nabis americoferus* and *Geocoris pallens* reduced populations of *L. hesperus* 71.3% and 92.9%, respectively, while larvae of *Chrysoperla carnea* had no significant effect (Leigh & Gonzalez 1976). Several heteropteran predators, including *Geocoris* spp., *Nabis* spp., reduviids, and predatory pentatomids, have been noted to feed on Lygus bugs in the laboratory (Knowlton 1949, Clancy & Pierce 1966, Perkins & Watson 1972, Propp 1982, Chow et al. 1983, Young 1989a, Arnoldi et al. 1991). Heteropteran predators, especially *Geocoris* spp., share some phylogenetic similarities with *Lygus* spp., and this may present some challenges in targeting chemical controls at Lygus bugs. In many cases, insecticides that are toxic to *Lygus* spp. will likewise be toxic to their heteropteran "cousins". This toxic relationship has been observed particularly with *Geocoris* spp., but probably exists for other Heteropterans as well.

Other species also have been associated with Lygus bug mortality. Spiders have been noted as Lygus bug predators in the field and laboratory (Young 1989a, 1989b, 1989c). The role of spiders is often underestimated in cotton, or is overlooked because of their catholic diet. Nevertheless, they can be very important predators of a number of cotton pests (e.g., Nyffeler et al. 1987, Sterling et al. 1992).

In addition to the predators and parasitic wasps and flies discussed above, a parasitic mite was recorded on nymphal and adult *L. lineolaris* (Young & Welbourn 1987), although its impact on populations is unknown. Rates of infestation reported by Young and Welbourn (1987) were quite variable but, ranged from 0 to 36% for *L. lineolaris*. The mite is capable of destroying at least early-instar nymphs. Ants also may be active predators of *Lygus* spp., particularly of the nymphal stages (JRR, pers. observation). The red imported fire ant (*Solenopsis invicta*) is a formidable predator of numerous insect pests of cotton in the eastern half of the Cotton Belt, and may be capable of destroying Lygus bugs in a number of habitats.

There are few records of pathogens of Lygus bugs in the United States (Table 1). Scales (1973) reported finding a mermithid nematode in an adult *L. lineolaris*. The fungus

Beauveria bassiana also has been isolated from *L. lineolaris* (Steinkraus 1996, Steinkraus & Tugwell 1997). Commercial formulations of *B. bassiana* have been tested against *Lygus* spp., and have yielded mixed results. Snodgrass and Elzen (1994) found that Naturalis-L (Fermone Corp., Phoenix AZ) had little effect on adult bugs, but numbers of nymphs were reduced 53.8% relative to untreated controls. They suggested that this material might be useful for early-season control, but would be inadequate for managing mid-season populations. Steinkraus (1996) and Brown et al. (1997) found that the efficacy of Mycotrol WP (Mycotech, Butte MT), a *B. bassiana* formulation, was greatly enhanced by the addition of a moderate rate of imidacloprid **--** the resulting mortality was significantly greater than that of either material alone. Integration of microbial materials with reduced rates of insecticides may hold considerable promise for managing Lygus bugs.

Challenges and Possibilities for Biological Control of *Lygus* spp.

The life histories of *Lygus* spp. present some serious challenges to biological control efforts. The extensive host ranges (see Young 1986 for review of host range for *Lygus lineolaris*) and high mobility of these bugs make it possible for Lygus bugs to exploit a wide range of habitats and host plants throughout the season. Widespread chemical applications would be questionably effective, costly, and potentially harmful over the range of habitats necessary to effect an impact on the bug's populations. However, use of actively searching natural enemies, that track and respond to the location and density of pest populations, may be advantageous for controlling such a pest. Successful suppression by natural enemies would need to start early in the season in off-crop habitats, and would need to occur across a majority of locations for an impact to be felt in the cotton system; requirements that do not preclude the use of biological controls to manage Lygus populations.

Day (1996) suggested that the native parasites of *Lygus* spp. are perhaps less effective in crop systems than in natural systems because the crop plants in question are themselves exotic to the United States. This suggestion assumes that the crop plants lack sufficient evolutionary history with the bugs and their native parasites to allow the parasites to use the necessary plant-related cues to find the host bugs. Although evidence to support such an hypothesis is lacking at the moment, the difference in parasite efficacy between crop plants and non-crop plants is striking and relevant to biological control in crop systems. Off-site biological control of *Lygus* spp., extending out over large areas and into non-crop systems, will probably provide the best opportunity for using natural enemies for suppressing *Lygus* spp. populations (see Schuster 1987). Area-wide approaches can be most cost-effective early in the season, when pest populations are low, and the number of habitats available for colonization is limited (see Knipling 1992 for discussion). In addition, off-site natural habitats are seldom treated with insecticides, making them ideal systems for natural enemies to function effectively.

Within crop systems, a combination of microbial agents and insecticides, as noted above, may provide a useful early-season tool for managing Lygus populations. This approach would reduce the impact of the intervention on beneficial species, and would help minimize the risk of flaring secondary pests. More work is needed with the microbials to make sure they can be used effectively with consistency. Ultimately, it would appear that a suite of practices will need to be brought to bear to manage *Lygus* spp., and these practices will need to range well beyond individual cotton fields if they are to be effective at the population level. Use of active biological control agents, such as predators and parasites, may be the ideal method for locating and suppressing Lygus bugs in diverse habitats, in effect using "search and destroy" tools, while pathogenic agents may prove to be valuable management tools in the cotton field itself.

Needs for Biological Control of *Lygus* spp.

Understanding the Activity of Resident Natural Enemies

It is important that the native natural enemy complex attacking *Lygus* spp. be identified and quantified. There are numerous tantalizing hints that predators and parasites can inflict considerable mortality on Lygus populations, but solid data are sadly lacking. Recent tools, such as the DNA method noted above (for identifying immature parasites) and immunotechniques (Hagler et al. 1991, 1992), provide new opportunities to identify and quantify predator and parasite activity. Large-scale studies must be undertaken to permit detailed analyses of parasitism and predation in multiple habitats and over time to begin understanding the dynamics of Lygus bugs in relation to their natural enemies. This information will allow us to devise total crop management packages that conserve important natural enemies. It also will help us to determine where weak links exist **--** time periods or habitats where *Lygus* spp. can build up their populations with little or no pressure from natural enemies. Identifying these weak links will allow us to target those habitats or time periods with appropriate chemical, biological, or cultural controls to suppress bug populations.

Augmentative Release Technology

Because biological control agents often have the ability to actively search out targets, and have limited environmental impact, the use of released natural enemies, particularly early in the season, may hold considerable promise for managing populations of *Lygus* spp. in and outside of crop systems. To be successful, the appropriate natural enemy(-ies) must be identified, cost-effective and quality-maintaining rearing methodology must be devised, and appropriate release habitats and timing must be identified (Obrycki et al. 1997). Releases could be made on an area-wide basis into a variety of natural habitats that serve as reservoirs for Lygus bugs, but are untreated with insecticides (Debolt 1987; see above). For example, data from studies of *Anaphes iole* suggest that this parasite can destroy a large number of Lygus eggs in non-crop systems, indicating that this parasite might be a useful organism for release programs. Indeed, it has shown promise in release programs in other crops (Norton & Welter 1996). Releases may offer some outstanding opportunities to attack *Lygus* spp. on a population scale, particularly if these releases can be undertaken early in the season when Lygus populations are low.

Importation of Natural Enemies

To date, numerous efforts have been made to introduce exotic natural enemies into the United States (Coulson 1987, Jackson et al. 1995). Successes of such programs against highly mobile pests, such as *Lygus* spp., are infrequent. Nevertheless, establishment of an effective natural enemy may contribute sufficient mortality to that already occurring to provide adequate Lygus population suppression. Rather than seeking a silver bullet natural enemy, we should look for one that adds to the mortality already occurring, rather than simply removing replaceable mortality (i.e., loss that would occur anyway). Establishment of an effective natural enemy also would provide long-term suppression without additional inputs (e.g., augmentative releases), accruing additional savings as the years pass. Continued efforts are warranted in this area.

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Table 1. Some natural enemies of *Lygus* spp.

Species	Stage attacked[1]	Origin[2]	References
Parasites			
Anaphes iole	E (E)	native	Clancy & Pierce 1966, Stoner & Surber 1969
Polynema pratensiphagum	E (E)	native	Krombein et al. 1979
Leiophron uniformis	N	native	Clancy & Pierce 1966, Debolt 1981
Leiophron schusteri	N	exotic	King et al. 1996
Peristenus pallipes	N (N,A)	native	Lim & Stewart 1976
Peristenus pseudopallipes	N (A)	native	Lim & Stewart 1976
Peristenus stygicus	N	exotic	Hedlund & Coutinot 1983
Peristenus digoneutis	N	exotic	Day et al. 1990, Day 1996
Peristenus rubricollis	N	exotic	Jackson et al. 1995
Peristenus nigricarpus	N	exotic	Jackson et al. 1995
Phasia (=*Alophorella*) *aeneoventris* (Tachinid fly)	N	native	Arnaud 1978
Phasia (=*Alophorella*) *fumoea* (Tachinid fly)	N	native	Arnaud 1978
Phasia (=*Alophorella*) *pulversa* (Tachinid fly)	N	native	Arnaud 1978
Phasia robertsonii (Tachinid fly)	A	native	Day 1995
Predators			
Nabis alternatus Damsel bug	N	native	Perkins & Watson 1972
Nabis americoferus Damsel bug	N	native	Leigh & Gonzalez 1976
Geocoris punctipes Big-eyed bug	E, N	native	Dunbar & Bacon 1972
Geocoris bullatus Big-eyed bug	E, N	native	Chow et al. 1983
Geocoris pallens Big-eyed bug	E, N	native	Leigh & Gonzalez 1976
Podisus maculiventris Spined soldier bug	N	native	Young 1989a
Zelus cervicalis Leafhopper assassin bug	N	native	Young 1989a
Sinea diadema Spiny assassin bug	N	native	Young 1989a
Lasioerythraeus johnstoni	N	native	Young & Welbourn 1987
Phidippus audax Jumping spider	A	native	Young 1989b
Oxyopes salticus Striped lynx spider	A	native	Lockley & Young1987
Pisaurina mira	A	native	Young 1989c
Metaphidippus galathea Jumping spider	A	native	Young 1989a
Phidippus clarus Jumping spider	A	native	Young 1989a
Thiodina puerpera	A	native	Young 1989a
Pathogens			
Beauveria bassiana	N, A	native	Steinkraus & Tugwell 1997
Mermithid sp. (Nematode)	A	native	Scales 1973

[2]Stage attacked: E: egg; N: nymph; A: adult; a letter followed by another, parenthetical letter in parentheses indicates that the bug is attacked in one stage (nonparathetical) and emerges from the parenthetical stage.

[2]Native: organism native to the United States; Exotic: imported from outside of the Nearctic region into the United States.