HOST PLANT PREFERENCES OF TARNISHED PLANT BUG:
A FOUNDATION FOR TRAP CROPS IN COTTON

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Abstract

Field and field cage studies were conducted on the Plant Science Research Farm at Mississippi State University to compare feeding and ovipostion preference of the tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois) and the tobacco budworm, *Heliothis virescens* (F.) on several host plants. Preferred feeding and ovipostion hosts will be used as trap crops for tarnished plant bug and as a refuge crop for tobacco budworm genotypes susceptible to transgenic cotton expressing endotoxin proteins of *Bacillus thuringiensis*. Observations were made on caged plants exposed to adults of both species and on field plots exposed to natural infestations of insects. Redroot pigweed, *Amaranthus retroflexus* L. was the most preferred host for tarnished plant bug. Kenaf, *Hibiscus cannabinus* L. may also be a useful trap crop plant for tarnished plant bug. Velvetleaf, *Abutilon theophrasti (*medicus), was the most preferred host for tobacco budworm. Sesame, *Sesamum indicum* L. and pigeon pea, *Cajanus cajan* (L.)Huth may also have value as plants for a refuge crop. Screening results obtained in 1996 are reviewed relative to plans for testing trap crops in 1997.

Introduction

Miridae contains many phytophagous insects commonly called plant bugs because many of them feed on plant juices. All of these insects have piercing-sucking mouthparts. *Lygus* is an economically important genus that belongs to this family. There are approximately 43 species of the genus *Lygus* of which two species are recognized pests of cotton, *Gossypium hirsutum* L. The tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), is found throughout the United States, and in the western United States, the western tarnished plant bug *Lygus hesperus* (Knight) is found. Many other species of mirids feed on cotton including the cotton fleahopper *Pseudatomoscelis seriatus* (Reuter) and the clouded plant bug *Neurocolpus nubilus* (Say). Most mirids, especially *L. lineolaris*, are extremely polyphagous (Wilson 1984). Snodgrass et al. (1984) observed tarnished plant bugs (*L. lineolaris*) feeding on more than 169 species of plants from 36 plant families in Mississippi, Arkansas, and Louisiana. Young (1986) recorded that plant bugs feed on almost 400 species of plants in the United States. Plant bugs prefer plants which are near the flowering stage of plant phenological development and populations tend to move accordingly (Snodgrass 1984, Fleischer and Gaylor 1987).

The tarnished plant bug is one of the most important economic insect pests of cotton in the southeastern United States (Snodgrass 1993). Although this pest can damage cotton throughout most of the growing season, economic damage is likely to occur from first square to early bloom. Excessive feeding by the tarnished plant bug may result in delayed crop maturity which can lead to decreased yields (Layton 1995). This delayed maturity is an important component of cotton production in the Mississippi Delta. Damage symptoms such as aborted terminals, swollen nodes, shortened internodes, excessive vegetative growth, and delayed fruiting have been described by Scales and Furr (1968) and Tugwell et al. (1976). Although tarnished plant bug densities and subsequent damage to cotton varies from year to year, the importance of tarnished plant bug as an economic pest of cotton has increased because of an emphasis on early crop maturity (Layton 1995).

The tarnished plant bug is considered a key pest of cotton in the Mississippi Delta because it is often the first pest that requires control measures during the growing season. Sprays targeted at tarnished plant bug reduce natural enemies and often trigger outbreaks of other pests, especially the tobacco budworm *Heliothis virescens* (f.)and the cotton bollworm *Helicoverpa zea* (Goddie). Traditionally, tarnished plant bugs have been controlled in Midsouth cotton with insecticides. Treatments have typically begun as the plant reached first square and are continued as needed later in the season. Plant bugs are often controlled later in the season by insecticides aimed at other pests, especially those aimed at *H. virescens* and *H. zea*. In recent years, however, efficacy of insecticides for tarnished plant bug control has been reduced. Snodgrass (1988, 1995, 1996) and Elzen et al.. (1992) describe insecticide resistance in Midsouth populations of tarnished plant bug. Higher population densities are being observed in cotton later in the growing season (Layton 1995), partially because indirect suppression of these populations by sprays targeted at other pests is no longer effective. This reduced suppression of tarnished plant bug by sprays targeted at *H. virescens* and *H. zea* will likely be further reduced with expanded deployment of transgenic cottons expressing endotoxin proteins of *Bacillus thuringiensis* (Bt cotton). Because of the likely reduction in insecticide use in Midsouth cotton, growers need an alternative approach for tarnished plant bug management.

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As early as 1964, Stern and co-workers in California proposed alternative means for controlling *L.. hesperus* in cotton. They designed an alfalfa harvest strategy for the San Joaquin Valley of California that reduced the movement of *L. hesperus* into cotton (Stern 1964, 1969). Alfalfa was harvested in alternate swaths so that two ages of alfalfa growth occurred in the field simultaneously. This strategy was adopted in a modified form by area growers and was used with some limited success. However, it's use was short lived because growers typically used contract custom harvesting and the staggered harvest intervals were perceived to be too difficult to manage. The technical feasibility of manipulation of tarnished plant bug densities in a cotton system was clearly established, but the economic cost and management difficulties favored continued use of insecticides.

The interplanting of alfalfa with cotton was clearly a technical success in demonstrating an alternative control strategy for *L. hesperus* in the western United States (Stern 1964 ,1969, Sevacherian 1973, Godfrey et al 1994). Since these early studies (Stern 1964, 1969), other scientists have demonstrated the possible manipulation of tarnished plant bug through management of preferred host plants, both cultivated and wild hosts. Alfalfa was studied by Schuster (1980) as a potential trap crop for tarnished plant bug in Mississippi cotton. In additional studies in California, Mueller and Stern (1973) also found that accurate timing of pesticide treatments to safflower before *L. hesperus* dispersal to cotton significantly reduced densities of *L. hesperus* in cotton. Recent studies by Fleischer et al (1988) and Fleischer and Gaylor (1987) in Alabama have demonstrated the potential value of using wild host plants as trap crops for tarnished plant bugs. Fleischer et al. (1988) and Snodgrass (1994) showed that management of natural host plants either by mowing or with insecticide treatment could be an effective method in reducing movement of tarnished plant bugs into cotton. However, timing of treatment or mowing is critical because destroying the host at the wrong time can flush the insects to a susceptible crop. Collectively, the literature strongly supports the concept of exploiting the preference of tarnished plant bugs for different flowering plants as a management tactic. Timing and an understanding of pest and host are critical in that the host plant species must act as a trap crop rather than a nurse crop that produces and releases large densities of tarnished plant bugs into cotton or other crops.

Bt cottons have been developed and are commercially available to Midsouth growers (Luttrell and Herzog, 1994). These insecticidal plants are only effective on lepidopteran pests and they have no direct effect on other pests such as tarnished plant bug and the boll weevil, *Anthonomis grandis grandis* (Boheman). However, indirect effects associated with reduced insecticide input and density relationships to other arthropod species are likely. Luttrell and Caprio (1994) indicated that fewer beneficial species would be found in Bt cotton systems as compared to unsprayed non-Bt cotton system because of density relationships. Because of the indirect effect on tarnished plant bugs that insecticide treatments targeted at other pests and the trend toward reduced use of insecticides in areas where boll weevil has been eradicated and in Bt cotton, the pest status of tarnished plant bugs is likely to increase. Bt cotton promises to be an effective means of controlling *H. virescens* and *H. zea* in cotton. However, with a resistant gene frequency as high as 1 in 1000 (Gould et. al. 1995), severe resistance problems can develop in only a few generations. Models predict that when refuges (portions of a pest population not selected for resistance and maintain frequency of susceptible genotypes) of only 5-10% are incorporated into a management system, dramatic increases in the effective life of Bt cotton are projected. Presently, regulatory agencies and industry groups developing Bt cotton require farmers to accept one of two options for creating refuges for Bt cotton. One states that for every 100 acres of Bt cotton planted, 25 acres of non-Bt cotton can be planted and treated for lepidopteran pests. The other states that for every 100 acres of Bt cotton planted, 4 acres of non-Bt cotton must be planted and not treated for lepidopteran pests (Luttrell and Caprio 1996). Given that refuges can extend the life of Bt cotton and that trap crops can successfully manage plant bugs, could one planting of different host plants satisfy both? Certainly, non-cotton refuges would be preferred by seed growers interested in maintaining the genetic purity of seed-increase crops.

H. virescens and *H. zea* are known to be major pests in cotton and overwinter as diapausing pupae in the Midsouth. Populations are usually their lowest during spring emergence. They emerge approximately 1.5 months before cultivatable crops are available, and the F_1 larval generation depends on early season wild hosts for survival (Stadelbacher 1979). Roach (1975) reported that *H. virescens* populations, especially those in early spring and fall, are dependent on only a few major plant species. Stadlebacher (1986) has compiled a list of suitable host plant species naturally occurring in the Mississippi Delta. The heliothines are also attracted to other cultivated crops such as grain sorghum, corn, and soybean (Hillhouse and Pitre 1975, Buschman et al. 1980). Based on the abundance of information on host preferences of tobacco budworm, cotton bollworm, and tarnished plant bugs, it seems possible that a refuge of cultivated and non-cultivated hosts could be realistically established to maintain susceptible populations of heliothines and serve as a trap crop for tarnished plant bug. The purpose of this study is to develop a trap crop system that could be used to manage tarnished plant bugs in Mississippi cotton and to provide a suitable refuge for *H. virescens* and *H. zea* genotypes susceptible to Bt cotton. Since the goal of this research is to purposely plant a mixture of preferred plants to attract insects away from cotton, the selected host plants must be easily cultivated in Midsouth cotton field environments as well as be preferred as ovipostion and feeding hosts for both pests.

Materials and Methods

A list of suitable hosts was made from a comprehensive literature search and conversations with research scientists. The list was shortened based on availability of seed and preferred growth characteristics of the host species. Species were then planted and further narrowed based on seed germination and growth. Once a suitable list of candidate plants was developed, field and greenhouse studies were conducted to compare ovipostion and feeding preferences in caged and natural environments.

For each plant in the original list of host plants, seeds were ordered and planted. The original list of plants was quite large and included the following species: daisy fleabane, *Erigeron philadelphicus* L., *Coreopsis spp* Nutt., wild geranium *Geranium dissectum* L., sesame, *Sesamum indicum*, velvetleaf, *Abutilon theophrasti*, wild carrot, *Dacus carota* L., curly dock, *Rumex crispus* L., common lambsquarter, *Chenopodium album* L., marestail, *Conyza cannadensis* L., wild mustard *Brassica kaber* L., redroot pigweed, *Amaranthus retroflexus* L., smooth pigweed, *Amaranthus hybridus* L., common ragweed, *Ambrosia artemisifolia* (L.) Descourt, giant ragweed, *Ambrosia trifida* L., alfalfa, *Medicago sativa* L., crimson clover, *Trifolium incarnatum* L., hairy vetch, *Vicia villosa* Roth, rape, *Brassica napus* L., evening primrose, *Oenothera biennis* L., hoary vervain, *Verbena stricta* Vent., narrow leaf vetch, *Vicia angustifolia* Reich., common vetch, *Vicia sativa* L., cotton, *Gossypium hirsutum*, corn, *Zea mays* L. , kenaf, *Hibiscus cannabinus*, soybean, *Glycine max* L., sorghum, *Sorghum bicolor* (L.)Moench, pigeon pea, *Cajanus cajan*, grain amaranth *Amaranthus* spp. L., and sunflower, var. Peridovic.

Because of the failure of some species to grow or failure to reach desired phenological stages relative to cotton, the list of plants was further reduced. Plants species that were retained for further studies were: cotton, soybean, kenaf, redroot pigweed, smooth pigweed, sesame, wild mustard, velvetleaf, corn, sorghum, pigeon pea and sunflower (Table 1).

Field Study

Two different field tests were planted. The first field test consisted initially of 15 treatment species, replicated 4 times for a total of 60 6x6 meter plots. Each plot contained 18 row meters of each the alternate non-cotton species and 18 row meters of cotton as the comparative standard treatment. Because of germination and growth problems, the initial 60 plots were reduced to 28 useable 6x6 meter plots consisting of 5 treatment species. The original plan included three stages of cotton compared to the alternate hosts. Due to growing problems, plots were used as they reached the desirable phenological stage. Because of this, each stage of growth included cotton compared to cotton (3 stages x 4 replicates=12 cotton compared to cotton plots; 4 alternate host species x 4 replicates=16 plots--16+12=28). The final treatment species included kenaf, redroot pigweed, soybean, velvetleaf, and cotton compared to cotton.

The second field test consisted of 9 treatment species with 4 replicates of each for a total of 36 6x6 meter plots. The same plot design was used in the second field trial as in the first. Observations were similar for both studies. Species used were sesame, pigeon pea, corn, sorghum, soybean, cotton, grain amaranth, kenaf, and sunflower. compared to cotton.

Each week plant growth measurements and numbers of natural populations of heliothines and tarnished plant bugs were determined by visual observations. The monitoring procedure was done for six weeks during the first study and for four weeks with the second study. At flowering stages of plant growth (i.e. those preferred by both species), 6x6meter mesh cages were placed over the plots and 200 adult tarnished plant bugs (ca. 6-8 days old) were released into the cage. These tarnished plant bugs were received as adults from a colony at the USDA-ARS, SIML in Stoneville, MS. These bugs were reared on sterilized green beans in one gallon ice cream containers. Observations were made at one and five days after release to record location of the plant bugs on the different host plants. Two days after the tarnished plant bug release, 20 gravid *H. virescens* moths from the USDA-ARS, CSRL rearing facility located on the MSU campus were released into the cage. The number of *H. virescens* eggs were counted on each host species two days after moth release. Ten days after the release of tarnished plant bugs, nine row feet of each species in the paired plot was cut at the soil surface with pruning shears. This plant material was placed in paper grocery sacks, weighed and stored in the laboratory at room temperature for ten days. The bags were opened after ten days and the number of tarnished plant bug nymphs observed was recorded. All data were studied by analysis of variance and means were separated using Student Newman-Keul's test (SAS Institute 1988).

Greenhouse Study

To further investigate ovipostional preferences, a greenhouse study was also conducted where both pest species were given a choice between several possible hosts. Species of plants tested are listed in Table 1. They were grown in one gallon plastic pots in greenhouses at the Plant Science Research Farm, Mississippi State University. Potted plants were measured weekly to record growth and phenological development. When plants reached the appropriate stage of plant development (i.e. flowering) the pots were then placed in 6x6 meter cages covered in nylon mesh cloth. Plants were arranged in six rows with each row containing 9 to 13 species of plants. Plant heights were recorded before 200 adult tarnished plant bugs (ca. 6-8 days old) were released into the cage. Observations of host preference were made at one and five days after release. Two days after the initial tarnished plant bug release, 20 gravid *H. virescens* moths were also released into the cage.

Two days later the total number of eggs on each individual plant was counted. Ten days after the release of 200 tarnished plant bug, the cage was removed and each potted plant was cut at the soil surface, placed in a paper grocery sack and weighed. The sacks containing the plant tissue were then stored for ten days after cutting at which time they were opened and the number of tarnished plant bug nymphs was counted and recorded. Data were studied by analysis of variance and means were separated using Student Newman-Keul's test (SAS Institute 1988).

Results and Discussion

In the first field study, five species of plants were compared to cotton. These species were cotton, velvetleaf, redroot pigweed, kenaf, and soybean (Table 1). Plant population densities of each species within each plot were taken and plants were measured each week to obtain an average height of each species. Numbers of naturally occurring tarnished plant bugs and heliothines were recorded on each of the species by observing twenty five terminals of each species within the plot. Observations were made on Julian dates 170, 178, 184, 191, 198, and 205. The data were collectively pooled and analyzed for this report (Tables 2-3). More tarnished plant bugs were found consistently on redroot pigweed than any other plant species (Table 2). Velvetleaf tended to be the most preferred oviposition host for *H. virescens*. Redroot pigweed tended to be a poor host for *H. virescens*(Table 2).

When tarnished plant bugs were released in the field cages, more were observed on kenaf and redroot pigweed than any other species, however differences were not observed five days after release (Table 4). When *H. virescens* moths were released into the cages, more eggs were oviposited on cotton than all other species except velvetleaf (Table 4). When data collected on cotton were analyzed separate from data collected on other species, there was no difference in tarnished plant bug densities one or five days post release or in *H. virescens* eggs found two days post release, although numerical trends suggested that pigweed and kenaf were preferred tarnished plant bug hosts (Table 4) and that velvetleaf attracted tobacco budworm ovipostion away from cotton (Table 5).

Ten days after release of tarnished plant bugs, tissue of the plants was cut. There was significantly more nymphal emergence both per bag of tissue and per gram of tissue for redroot pigweed paired with cotton than with other paired plots (Table 4).

In the second field study, significant numbers of naturally occurring tarnished plant bugs were not observed. Naturally occurring populations of heliothines also were not found to be significant among the species. However, numerical trends showed that paired plots containing sesame, pigeon pea, cotton, and corn compared to cotton were preferred ovipostion and feeding hosts of tobacco budworm and cotton bollworm. Tarnished plant bugs were released only on plots with cotton compared to sesame and sunflower. No significant differences were measured because of lack of replication. No differences were seen in the number of tobacco budworm eggs when moths were released in cages containing sesame and pigeon pea compared to cotton.

In the study with caged greenhouse plants, the number of adult tarnished plant bugs observed on plants was significantly higher one and five days after release on redroot pigweed than all other plants. Smooth pigweed was more preferred by tarnished plant bugs one and five days after release than were all species of plants other than redroot pigweed (Table 5). When *H. virescens* moths were released, more eggs were observed on velvetleaf two days after release than on any other plant species (Table 6). Ovipostion on sesame was intermediate between that on velvetleaf and that on other plant species (Table 6). More tarnished plant bug nymphs were seen emerging from redroot pigweed tissue than tissue from other plants (Table 6). However, when compared on a nymph per gram of material basis, there were significantly similar numbers of nymphs per gram of plant tissue from kenaf and redroot pigweed (Table 6).

Collective results of these field and field cage studies indicate that both pest species prefer some host plants over cotton. Redroot pigweed is most certainly a preferred host for tarnished plant bug. Kenaf appears to be a realistic candidate as a component of a trap crop system for tarnished plant bug. Velvetleaf is the most preferred host for tobacco budworm, as expected (Schneider and Roush 1986). However, sesame and pigeon pea also appear to have some potential value as refuge crops for tobacco budworm and bollworm. This may be important because velvetleaf is a noxious weed in the Midsouth. Convincing growers to plant velvetleaf may be extremely difficult.

Field studies will be conducted in 1997 to determine if strips of a mixture of different species (8-16 rows wide) planted across cotton fields will reduce numbers of tarnished plant bugs in adjacent cotton and increase survival of tobacco budworm in the strip area. The most preferred species identified in these 1996 experiments will likely be key components of the trap/refuge crop system.

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Table 1. Potential plant species to be used as a trap/refuge crop for tarnished plant bug, tobacco budworm, and cotton bollworm in Midsouth cotton.

Cotton*	Rape**	Common vetch***
Soybean*	Marestail***	Narrowleaf vetch***
Corn*	Evening primrose***	Sunflower*
Sorghum*	Hoary vervain***	Grain amaranth*
Kenaf*	Wild mustard**	Common lambsquarter***
Redroot pigweed*	Pigeon pea*	Curly dock***
Smooth pigweed*	Alfalfa***	Common ragweed***
Velvetleaf*	Crimson clover***	Giant ragweed***
Wild geranium***	Daisy fleabane***	*Coreopsis spp.****

* Used in both field test and greenhouse study
** Used only in greenhouse study
*** Did not show promise

Table 2. Natural infestation of (non-cotton) alternate hosts by tarnished plant bug (TPB) and tobacco budworm (TBW) in a paired plot field study in 1996

	TPB/25 term	TBW egg/25 term	TBW larvae/25 term
Treatment			
Cotton vs. Cotton	0.0b	7.3ab	1.89a
Kenaf vs. Cotton	0.0b	0.4b	0.08b
Redroot pigweed vs. Cotton	2.5a	0.0b	0.00b
Soybean vs. Cotton	0.9b	0.8b	0.08b
Velvetleaf vs. Cotton	0.0b	18.3a	2.23a

*Means within a column followed by similar letters do not differ significantly

Table 3. Natural infestation of cotton by tarnished plant bug (TPB) and tobacco budworm (TBW) in a paired plot field study in 1996

	TPB/ 25 term	TBW eggs/25 term	TBW larvae/25 term
Treatment			
Cotton vs. Cotton	0.04a	7.44a	3.96a
Kenaf vs. Cotton	0.00a	6.52ab	2.62a
Redroot pigweed vs. Cotton	0.10a	2.65b	0.60b
Soybean vs. Cotton	0.05a	6.00ab	3.33a
Velvetleaf vs. Cotton	0.05a	5.57ab	3.57a

*Means within a column followed by similar letters do not differ significantly

Table 4. Ovipostion and feeding preference of tarnished plant bug (TPB) on alternate (non-cotton) hosts and cotton in a paired plot field study in 1996.

	TPB adults/ 60 row feet (Days post release)				TPB nymphs/9 row feet	
Treatment	Alt host 1day	Alt host 5 days	Cotton 1 day	Cotton 5 days	Alt host	Cotton
Cotton vs Cotton	10.0b	1.0a	10.0a	0.0a	2.0c	0.0b
Cotton vs. Kenaf	32.3a	13.5a	9.3a	4.3a	10.3b	0.8b
Cotton vs. Redroot pigweed	39.0a	14.5a	4.0a	1.8a	83.5a	2.5a
Cotton vs. Soybean	10.0b	1.3a	7.7a	1.0a	1.3c	0.3b
Cotton vs. Velvetleaf	1.8b	0.0a	8.8a	1.8a	0.3c	0.7b

*Means within a column followed by a similar letter do not differ significantly

Table 5. Ovipostion and feeding preference of tobacco budworm (TBW) on alternate (non-cotton) hosts andcotton in a paired plot field study in 1996.

	TBW eggs/60 row feet	
Treatment	Alternate host	Cotton standard
Cotton vs Cotton	21.7ab	35.3a
Cotton vs. Kenaf	1.3b	53.8a
Cotton vs. Redroot Pigweed	0.0b	59.3a
Cotton vs. Soybean	7.8b	45.5a
Cotton vs. Velvetleaf	57.3a	29.8a

*Means within a column followed by a similar letter do not differ significantly

Table 6. Ovipostion and feeding preference of tarnished plant bug (TPB) and tobacco budworm (TBW) on potential trap/refuge crop plants in a cage study using greenhouse grown plants.

Treatment	Tarnished plant bugs per plant (days post release) 1 day	5 days	TBW eggs per plant	TPB nymphs per plant	TPB nymphs per gram
Cotton	0.3b	0.3c	0.8 c	0.1c	0.00b
Soybean	0.8b	0.2c	0.3 c	0.1c	0.00b
Velvetleaf	0.8b	0.1c	22.6a	0.0c	0.00b
Smooth pigweed	1.7b	2.1b	0.0 c	0.6c	0.00b
Redroot pigweed	3.3a	3.3a	0.0 c	4.3a	0.02a
Kenaf	0.9b	0.6c	0.1 c	2.3b	0.01a
Sesame	0.3b	0.1c	10.8b	1.4bc	0.01b
Pigeon pea	1.6b	0.4c	1.4 c	0.1c	0.01b
Corn	1.5b	0.5c	2.7 c	0.1c	0.00b
Sorghum	0.4b	0.0c	0.1 c	0.0c	0.00b
Wild Mustard	0.7b	0.7c	0.0 c	0.0c	0.00b

*Means within a column followed by similar letters do not differ significantly