Tarnished Plant Bug (Hemiptera: Miridae) on Selected Cool-Season Leguminous Cover Crops[1]

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ABSTRACT Replicated field trials indicated that tarnished plant bug (TPB), *Lygus lineolaris* (Palisot de Beauvois) (Hemiptera: Miridae) attained relatively-high densities on hybrid vetches, *Vicia sativa* L. X *V. cordata* Wulf cv 'Cahaba White' and 'Vantage,' lower densities on crimson clover, *Trifolium incarnatum* L. cv 'Dixie,' and particularly-low densities on subterranean clover, *Trifolium subterraneum* L. cv 'Mt. Barker.' Densities of TPB were also relatively low on an additional 10 types of subterranean clover, including 7 cultivars representing *T. subterraneum,* 1 cultivar of *T. brachycalycinum* Katznelson and Morley, and 3 of *T. yanninicum* Katznelson and Morley. Field longevity trials indicated that late-instar and adult TPB lived longer when caged on crimson clover than on hybrid vetch, which in turn supported better survival than did subterranean clover. When adult TPB were caged on hybrid vetch or subterranean clover with or without floral and fruiting structures, there was no evidence that the presence of these structures prolonged TPB survival on either crop. In laboratory choice tests with flowering and fruiting shoots of three cover crops, TPB preferred crimson clover over hybrid vetch, which in turn was more attractive than subterranean clover. When shoots were presented after reproductive structures had been excised, there was no statistically-significant preference by TPB.

KEY WORDS Insecta, *Lygus lineolaris,* cover crops, crimson clover, *Trifolium, Vicia,* subterranean clover, vetch.

Intercrop transfer of mobile pests can lead to major problems (Kennedy and Margolies 1985). For example, tarnished plant bug (TPB), *Lygus lineolaris* (Palisot de Beauvois) (Hemiptera: Miridae), and other *Lygus* spp. can disperse from wild host plants, cover crops, or interplants, and cause damage to field, orchard, and row crops (Khattat and Stewart 1980, Gruys 1982, Davidson and Lyon 1987, Fleischer and Gaylor 1987, Tingey and Lamont 1988, Fleischer et al. 1989). There is increasing interest in the use of cover and green-manure crops for soil conservation and improvement (Power 1987). An evaluation of these crops for their suitability to agricultural pests such as *Lygus* spp. is required.

In a prior replicated field trial (Bugg et al. 1990), shake sampling indicated that TPB attained exceptionally-high densities on two hybrid vetches, *Vicia sativa* L. X

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V. cordata Wulf, cv 'Cahaba White' and 'Vantage;' lower levels on crimson clover, *Trifolium incarnatum* L. cv 'Dixie,' and lentil, *Lens culinaris* ssp. *culinaris* L. cv 'Chilean 78;' and particularly-low densities on subterranean clover, *Trifolium subterraneum* L. cv 'Mt. Barker.' Bugg et al. (1990) suggested that subterranean clovers may provide a relatively-unfavorable habitat for *Lygus lineolaris* because they lack extrafloral nectaries, present flowers at or beneath the foliar canopy, are self-pollinated and presumably lack floral nectar, and 'self-sow' their seed shortly after anthesis (Duke 1981, McGuire 1985). Thus, flowering occurs in a relatively shady, cool, and moist microclimate, and there may be little opportunity for TPB to feed on developing seed. Bugg et al. (1990) further speculated that subterranean clovers might prove particularly useful in farming systems for which TPB is a significant pest.

In the present study, we further explored the relationships of TPB to crimson clover, the two hybrid vetches, and subterranean clovers. The replicated trials include evaluation of field densities to test the prior results of Bugg et al. (1990), and trials evaluating differential survival and preference.

Methods and Materials

Field Experiments. Densities and longevities of tarnished plant bug were assessed in field trials conducted during 1988-89 at the Horticulture Farm, a 10-ha tract located at the University of Georgia, Coastal Plain Experiment Station, Tifton. We used plots devoted to multidisciplinary experiments for the studies hereafter referred to as Cover Crop Trials I, II, and III. The multidisciplinary experiments concerned minimum-tillage management of cool-season cover crops preceding warm-season vegetables.

Cover Crop Trial I evaluated 20 cover-cropping regimes preceding cucumber, *Cucumeris sativas* L. (Cucurbitaceae), and entailed a randomized complete block design with four replications. Plots comprised 6.1-m linear sections of bed; consecutive plots in a bed were separated by 0.305 m. Beds were 1.83 m wide (1.27 m, exclusive of tire tracks). Each plot was seeded to one of the crops listed in Table 1, in 4 rows spaced 0.305 m apart.

Cover Crop Trial II concerned eight cover-cropping regimes preceding cantaloupe, *Cucumis melo* L. var. *reticulatus* Seringe (Cucurbitaceae), and was conducted concurrently with Cover Crop Trial I. We employed a randomized complete block design with three replications. Each plot was 6.10 m in length and comprised 3, 1.83-m beds (1.27 m, exclusive of tire tracks), with intervening 0.305-m alleys. Each bed contained 4 rows spaced 0.305 m apart. The eight cover-crop regimes were: (1) 'Vantage' vetch; (2) common lentil; (3) subterranean clover; (4) crimson clover; (5) rye; (6) mustard; (7) a polyculture of the six crops previously mentioned; and (8) control, which received no seeds, but was otherwise treated similarly to other regimes. Where not otherwise indicated, cultivars of cover crops were the same as in Cover Crop Trial I.

Cover Crop Trials I and II were seeded using a tractor-drawn Stan-Hay seeder on 26 or 27 October, except for narrow-leafed lupin and 'Tyfon,' which were seeded on 2 November. Seeds were placed at approximately 0.6-cm depths. Both trials involved use of contact herbicide to prepare for subsequent experiments. On 27 March, the 2 interior rows of each cover-cropped plot were treated with glyphosate (1.68 kg/ha active ingredient); in each plot, the exterior two rows of

Table 1. Numbers of *Lygus lineolaris* per 21-cm diameter hoop on cool-season leguminous cover crops (Cover Crop Trials I and II).*

	Stage/Crop/Mean No. ± SEM (r = 7†)							
	Adults				Nymphs			
Sampling Date	Crimson Clover	Sub. Clover	Hybrid Vetches‡	P	Crimson Clover	Sub. Clover	Hybrid Vetches‡	P
April 4	1.6 ± 0.3b	0.1 ± 0.1c	4.0 ± 1.0a	0.0001	1.8 ± 0.4b	0.2 ± 0.1c	7.5 ± 1.4a	0.0001
14	2.5 ± 0.3a	0.1 ± 0.1b	2.7 ± 0.4a	0.0001	2.7 ± 0.8a	0.1 ± 0.1b	3.8 ± 0.9a	0.0001
24	0.5 ± 0.2b	0.1 ± 0.1b	2.3 ± 0.3a	0.0001	0.3 ± 0.1b	0.2 ± 0.1b	1.1 ± 0.3a	0.0039
Overall	1.5 ± 0.1b	0.1 ± 0.1c	2.5 ± 0.3a	0.0001	1.6 ± 0.4b	0.2 ± 0.1c	4.3 ± 0.7a	0.0001

* Analyses were by separate one-way ANOVA for each date, using transformed data ($y' = SQRT[y] + SQRT[y + 1]$). For each comparison, means followed by the same letter are not significantly different by Fisher's protected least significant difference.

† There were only six replications for hybrid vetch on April 24.

‡ On April 4, 'Vantage' vetch was employed for all 7 replications; on the other two dates, two plots of 'Cahaba White' vetch were used, and the remaining plots were of 'Vantage.' The two hybrid vetches share the same parental species and both have extrafloral nectaries.

cover crops were shielded from the herbicide. Inner rows of cover crop were killed by glyphosate, but throughout the trials there was no visible injury to plants in the outer rows, and we assume that there was no effect of herbicide on the results reported here. On 25 April, the center of each bed was cultivated with a fluted disk; on 26 April, each center was subsoiled, and immediately thereafter a rolling cultivator was employed. In Cover Crop Trial I, cucumber (cv 'XTH-1472' [ASGROW]) was sown on 27 April in a central row in each plot. Replanting was done on 4 May, to compensate for gaps. On 1 and 9 June, cucumber stands were thinned to 20 plants/plot. In Cover Crop Trial II, cantaloupe (cv 'Hiline') was seeded on 27 April, with groups of seeds at 0.915-m intervals. Each group comprised 4-12 seeds placed at intervals of approximately 15-25 cm. Thus, the interior 2 rows of cover crop were always replaced by a cucurbit. On 23 May, a sickle-bar mower was used to cut rye to a height of approximately 15 cm.

Throughout the studies detailed here, the outer rows of cover crops had no physical contact with the small cantaloupe or cucumber plants: 0.45 meters separated the outer rows of cover crops from the central rows of cucurbits. We therefore assume that there was little or no interference by the small cucurbit plants with the maturing cover crops.

Cover Crop Trial III concerned 11 cultivars of subterranean clover and two other legumes used as cover crops. In this experiment, we determined whether other subterranean clovers harbored densities of TPB similar to those for 'Mt. Barker,' and whether these differed markedly from those for two other cover crops. On 8 November, the following cultivars of *T. subterraneum* were sown, without prior inoculation, in unreplicated observation plots: 'Enfield,' 'Esperance', 'Howard,' 'Junee,' and 'Nangeela,' 'Talarook,' and an unnamed strain developed at Mississippi State University (hereafter termed the Mississippi ecotype). In addition, there were unreplicated plots of burclover, *Medicago polymorpha* (L.) ssp. *subspina* cv 'Circle Valley,' and lentil, cv 'Indian Head,' both sown following inoculation with the appropriate rhizobial bacteria. Also, the following subterranean clovers were seeded into two plots each (one with rhizobial inoculant, one without): 'Mt. Barker,' 'Koala' (*T. brachycalycinum* Katznelson and Morley), and 3 cultivars of *T. yanninicum* Katznelson and Morley: 'Larisa,' 'Meteora' and 'Trikkala.' The overall design of this trial was completely randomized, with each plot constituting a 3.05-m section of 1, 1.83-m bed. The bed comprised 4 rows spaced 0.305 m apart.

Densities of Tarnished Plant Bug. In a field experiment involving plots from both Cover Crop Trials I and II, we determined the densities of *Lygus lineolaris* on crimson clover, hybrid vetches ('Cahaba White' or 'Vantage' vetch), and subterranean clover. The 'Cahaba White' vetch was substituted in several cases for 'Vantage' because these two cultivars have shared parentage, similar densities of TPB, and because stands were poor in several of the plots of 'Vantage' in Cover Crop Trial I. Lentil was excluded from consideration because stands were devastated by root-knot nematodes. Sampling was conducted on 4, 14, and 24 April, and involved placing a circular, 21-cm-diameter hoop randomly amid the outside rows of cover crops. That is, we always sampled amid the living, unsprayed portions of cover-crop in each plot. The adult and nymphal TPB occurring within the hoop were counted. We sampled during cool, morning hours, and selected areas to be subsampled that were as widely separated as possible. We approached the plots slowly and cautiously, and enumerated those few adult *Lygus* that flew prematurely from the areas selected for subsampling. The areas circumscribed by the hoop were thoroughly searched, from the apical foliage to the soil surface. We believe that this is an excellent method for sampling *Lygus lineolaris,* given the planting arrangement (discrete rows of crop plants, allowing easy inspection of the soil surface). On each sampling date, three subsamples were taken per plot.

TPB densities were assessed in Cover Crop Trial III as above, except that only two subsamples were taken per plot. Sampling was conducted on 14 April, when all crops but 'Talarook' and the Mississippi ecotype were flowering and maturing seed.

Survival Trials. We conducted three studies on survival (Survival Trials I, II, and III), using plots from Cover Crop Trials I and II. Since our purpose was not to test effects due to gender, but to assess effects on longevity for a representative field-collected sample of TPB, we used field-collected adult or late-instar nymphal TPB of unknown age and undetermined gender. These tests do not provide absolute measures of longevity, but can be used to assess relative differences in survival due to treatment.

Survival Trial I employed enclosure cages of dimensions 16.0 × 23.5 cm, constructed of polyester netting (8 × 20 lines per cm) with Velcro® closures. Adult TPB were collected on the afternoon of 31 March, by sweeping weeds (Cutleaf eveningprimrose, *Oenothera laciniata* Hill, Onagraceae; *Verbena tenuisecta* Briquet, Verbeniaceae) with a fine-mesh aerial net. Four, randomly-assigned specimens of undetermined gender were transferred to each of 21 enclosure cages, and kept cool overnight in an ice chest. On the morning of 1 April, cages were randomly assigned, one to each plot, to crimson clover, subterranean clover, and 'Vantage' vetch. There were 7 replicate plots for each cover crop. One, 8-cm shoot of vegetation, where available including flowers and/or developing seed, was enclosed by each cage. Few plants of hybrid vetch were in flower at the time the study was started. Until 14 April, shoots were replaced only if they wilted or died. Thereafter, shoots were replaced frequently, to ensure availability of fresh flowers. In this and the subsequent two trials, survival by bugs was assessed daily.

Survival Trial II was initiated on 14 April. Nymphal TPB (the vast majority being of instars 4 and 5, but a few of instar 3) were collected by sweeping cover crops of crimson clover and hairy vetch with an aerial net. The nymphs were then caged on cover crops as above. In this study, a special effort was made throughout to provide fresh flowers on all three crops.

Survival Trial III was initiated on 10-11 May. Two factors were investigated: (1) crop (2 levels: hybrid vetch or 'Mt. Barker' subterranean clover); (2) fruiting structures (2 levels: with flowers and developing seed or with these structures clipped off; stipular extrafloral nectaries persisted on vetch under both these regimes). Adult TPB were collected from cutleaf eveningprimrose and caged on 10-cm shoots of hybrid vetch ('Cahaba White' [3 plots] or 'Vantage' [4 plots] vetch), or on 'Mt. Barker' subterranean clover (7 plots). Seven cages each containing 4 TPB, were allocated to each of the 4 treatments. Crop was the main-plot factor; the presence or absence of fruiting structures was assigned using a split-plot approach. The study was terminated on 23 May, because immediately thereafter the weather became very hot, and all experimental insects died.

In Survival Trials I and II, three indices were used to assess survival: (1) mean: average number of days survived (4 bugs caged per plot); (2) maximum: number of days survived by the longest-lived bug in each plot; and (3) minimum: number of days survived by the shortest-lived bug in each plot. In Survival Trial III, only the per-cage mean was used.

Laboratory Experiments. We conducted two choice experiments in the laboratory. In Choice Experiment I, we assessed preference of TPB for certain crops; Choice Experiment II concerned whether such preference is affected by removal of flowers and fruiting structures. Both experiments were conducted using continuous illumination.

Choice Experiment I comprised two trials, conducted on 30 April - 1 May, and May 2-3, 1989. Five plexiglass sleeve cages of dimensions 30 × 30 × 20 cm were used for each trial. Adult TPB were collected by sweeping stands of cutleaf eveningprimrose with an aerial net. For the first trial, 5 TPB were introduced into each cage; in the second trial, we used 8 TPB per cage. Each cage received one 20-ml bottle of distilled water, containing two, 10-cm shoots respectively of 'Dixie' crimson clover and 'Mt. Barker' subterranean clover, and one shoot of 'Vantage' vetch. The shoots contained both flowers and ripening seeds, and each crop was represented by approximately-equal amounts of vegetation. The shoots were chosen to be of approximately-equal height. Baseline data on plant availability were obtained by rustling foliage of the plants and thereby disturbing caged TPB, allowing 20 - 60 minutes to elapse, then counting TPB on each plant species. In these and all subsequent counts, we ignored TPB not observed on the plants. This procedure was repeated several times at the beginning of each trial; these initial data were termed control observations. We infer that if crops are equally available, approximately-equal numbers of TPB will settle initially on all three species, and that the initial counts should reflect non-significant differences among crops. As detailed in the section on statistical analysis, the data on initial settling were also used to weight or standardize preference data, and thereby compensate for differences in availability. Data on preference were obtained by counting TPB after longer periods without disturbance (6.5-11 hours), with no disturbances preceding additional observations. These longer periods would presumably allow insects to sample prospective host plants, and for any arrestant properties of these plants to become apparent. The first trial was initiated on 30 April at 1200 hours, (EDST), with control observations at 1300, 1330, 1400, 1430, 1500, and 1530; the test observations were made at 2200, and on 1 May at 0820 and 1000. The second trial was initiated on 2 May at 2015 hours, with control observations at 2045, 2125, 2145; test observations were made on 3 May at 0800, 1000, and 1200.

Choice Experiment II comprised two component trials conducted on 11-12 May and 13-14 May. Again, 5 Plexiglas cages were used in each trial. Sprigs of the three crops were obtained as above. Flowers and developing fruiting structures were excised, and the shoots placed immediately in bottles of distilled water. Adult TPB were obtained as above, and confined. We used 5 bugs per cage in the first trial, and 8 per cage in the second. The first trial was initiated at 1700 hours, 11 May, with control observations at 1730, 1800, and 1830, and test observations at 2100, and on 12 May at 0915, 1040, 1240, 1450, and 2215. The second trial was started on 13 May at 1250, with control observations at 1340, 1440, and 1520, and test observations at 1850 and 2110, and on 14 May at 1050, 1315, 1910, and 2025. TPB were counted as above.

In both choice experiments, trial was assigned as a main-plot factor, whereas crop was assigned based on a split-plot approach.

Statistical Analysis. Analysis of variance (ANOVA) was used in density, survival and choice experiments. Appropriate factorial and split-plot approaches were used. Effects not proven significant ($P < 0.05$) were discarded from ANOVA models. When F-tests indicated significant main effects, differences among more than two means were detected by Fisher's (protected) least significant difference (plsd) (Steel and Torrie, 1980, p. 176). Densities of adult and nymphal TPB were measured using the unified consideration of Cover Crops Trials I and II. These were assessed by two complementary approaches to ANOVA. Crop and insect phenologies may result in great differences in insect densities on different dates. Therefore, we used separate ANOVA for each sampling date. In cases where the relative rankings of cover crops did not differ through time, we also assessed overall effects through use of repeated-measures ANOVA, employing overall means from each plot to assess possible effects due to crop.

Where not otherwise noted, we analyzed untransformed data. In Cover Crop Trials I and II, we transformed count data ($y'=SQRT[y] + SQRT[y+1]$), in order to stabilize error variance. In Choice Experiments I and II, we used per-cage means for control and test observations. We also analyzed "standardized" or weighted values for the test observations. These were obtained by adding one to the mean number obtained from control observations in each cage, and dividing this into the corresponding mean from test observations. This procedure was intended to compensate for any underlying disparity in crop availability.

Data from Cover Crop Trial III were assessed by calculating a 95% confidence interval for the overall mean density of TPB on all subterranean clovers ($r = 16$), and determining whether the respective means for lentil and burclover fell within this interval.

Results

Field Experiments

Densities of Tarnished Plant Bug on Cover Crops. Hoop samples from Cover Crop Trials I and II (Table 1) confirmed the results of Bugg et al. (1990): TPB adults and nymphs were particularly abundant on the hybrid vetches, intermediate on crimson clover, and particularly scarce on subterranean clover.

Cover Crop Trial III indicated relatively-low densities of TPB on all strains of subterranean clover assessed (Table 2). A 95% confidence interval based on data from all plots of subterranean clover showed a mean per-subsample density of 0.41 ± 0.24. Mean densities in the unreplicated plots of lentil (2.25) and the 'Circle Valley' burclover (4.75) lie far above the upper limit, indicating that these values are significantly different.

Survival Trials. Results from Survival Trial 1 (Table 3) suggested a ranking of crimson clover = hybrid vetch > subterranean clover. Survival Trial II (Table 4) showed a significantly-greater survival on crimson clover than on hybrid vetch, but did not indicate any other statistically-significant differences. Results of Survival Trial III showed that mean survival was significantly better on hybrid vetch than on subterranean clover ($P = 0.0402$), with means 7.78 and 5.88 days, respectively. Surprisingly, there was no significant effect due to presence or absence of fruiting structures ($P = 0.6340$), with respective means 6.95 and 6.70 days.

Results were somewhat discrepant. Survival Studies I and III yielded significantly better survival of TPB hybrid vetches than on subterranean clover. Survival Study II indicated the converse, but in this case the means were not statistically different. As noted, the methods of the studies differed, as did weather conditions. Survival Trial III indicated statistically-significant differences in favor of hybrid

Table 2. Number of pooled adult and nymphal *Lygus lineolaris* per 21-cm diameter hoop on cool-season leguminous cover crops (2 subsamples per plot), 14 April, 1989 (Cover Crop Trial III).

Crop	Mean No. Per Subsample (± SEM, if cv was replicated)
Trifolium brachycalycinum	
'Koala'	0.6 ± 0.6
Trifolium yanninicum	
'Larisa'	0.1 ± 0.1
'Meteora'	0.6 ± 0.4
'Trikkala'	0.4 ± 0.4
Trifolium subterraneum	
'Enfield'	0.0
'Esperance'	0.3
'Howard'	0.3
'Junee'	0.3
'Mt. Barker'	0.8 ± 0.8
'Nangeela'	0.3
'Talarook'	0.3
Medicago polymorpha ssp. *subspina*	
'Circle Valley'	4.8
Lens culinaris ssp. *culinaris*	
'Indian Head'	2.3

Table 3. Survival of adult *Lygus lineolaris* caged on three cool-season leguminous cover crops (Survival Study I).

	Days Survived ± SEM (r = 7)			
Survival Index*	Crimson Clover	Subterranean Clover	'Vantage' Vetch	P†
(1) Mean	12.7 ± 1.4a	5.0 ± 1.1b	9.3 ± 1.0a	0.0007
(2) Maximum	27.1 ± 3.3a	10.7 ± 5.9b	16.6 ± 2.2ab	0.0011
(3) Minimum	3.7 ± 1.3	1.3 ± 0.8	4.3 ± 1.1	0.1277

* Indices are: (1) Mean: average number of days survived in each plot; (2) Maximum: number of days survived by the longest-lived bug in each plot; and (3) Minimum: number of days survived by the shortest-lived bug in each plot.

† Based on one-way ANOVA. In the event of a significant F-test, means followed by the same letter are not significantly different by Fisher's protected least significant difference.

vetches over subterranean clover. However, the differences were not great, perhaps because the study had to be curtailed due to wholesale death of the experimental insects with the onset of hot weather.

Two of three survival trials indicated that TPB survived longer on hybrid vetches than on subterranean clover, and one of two trials showed significantly greater longevity on crimson clover than on hybrid vetches.

Laboratory Experiments. Choice Experiment I yielded control observations that showed non-significant effects due to trial (P = 0.0631) and crop (P = 0.5246). The latter result seems to imply that the crops were equally available to the bugs. Test observations showed significant results both for trial (P = 0.0134) and crop (P = 0.0083); means for all three crops were significantly different from one

Table 4. Survival of *Lygus lineolaris* caged during late nymphal stadia on three cool-season leguminous cover crops (Survival Study II).

	Days Survived ± SEM*			
Survival Index†	Crimson Clover	Subterranean Clover	'Vantage' Vetch	P‡
(1) Mean	11.5 ± 1.8	7.8 ± 1.1	7.0 ± 1.1	0.0784
(2) Maximum	21.4 ± 4.5a	13.7 ± 1.6ab	10.0 ± 2.0b	0.0477
(3) Minimum	5.0 ± 0.9	3.8 ± 1.0	3.9 ± 0.6	0.5196

* For subterranean clover, r = 6, because one cage was damaged by a tractor, and data from that cage are excluded from the analyses. For crimson clover and hybrid vetch, r = 7.

† Indices are (1) Mean: average number of days survived in each plot; (2) Maximum: number of days survived by the longest-lived bug in each plot; and (3) Minimum: number of days survived by the shortest-lived bug in each plot.

‡ Based on one-way ANOVA. In the event of a significant F-test, means followed by the same letter are not significantly different by Fisher's protected least significant difference.

another. The hierarchy for crops was: 'Dixie' crimson clover (2.30) > 'Vantage' vetch (1.80) > 'Mt. Barker' subterranean clover (0.67) (mean numbers of bugs per crop sample given parenthetically). When standardized values were used, ANOVA showed significant effects both for trial ($P = 0.0048$) and crop ($P = 0.0268$), but there was only one significant difference between crops: crimson clover was preferred over subterranean clover.

Choice Experiment II showed a highly-significant effect due to trial ($P = 0.0003$), but no significant effect caused by crop ($P = 0.4998$). The test observations showed a significant effect due to trial ($P = 0.0122$), but a non-significant result was obtained for crop ($P = 0.1007$). Mean numbers of bugs for crimson clover, 'Vantage' vetch, and subterranean clover were respectively 1.18, 1.73, and 1.10. Use of standardized values showed no significant effect due to trial ($P = 0.6025$) or crop ($P = 0.1817$). Thus, when only vegetative structures were presented, there was no clear-cut evidence for preference among crops.

Discussion

Field experiments indicated that during April and early May, TPB attained relatively-high densities on the hybrid vetches, lower levels on crimson clover, and particularly-low densities on all subterranean clovers assessed. Taken together, the survival studies showed that late-instar nymphal and adult TPB lived longer when caged on crimson clover than on hybrid vetches, which in turn supported greater survival than did subterranean clover. When adult TPB were caged on hybrid vetches or subterranean clover with or without floral and fruiting structures, there was no evidence that the presence of these structures prolonged TPB survival on either crop. When bugs were presented in a choice arena with flowering and fruiting shoots of three cover crops, crimson clover was preferred by adult TPB over subterranean clover. Evidence was equivocal as to whether crimson clover was more attractive than hybrid vetch, and whether the latter was more attractive than subterranean clover. When shoots were presented after reproductive structures had been excised, there were no clear-cut preferences by TPB. It is important to note that, for crimson clover and vetch, nectar flow may have been disrupted during these experiments, which may have influenced results.

In interpreting our results, it is important to keep in mind some key biological points, also detailed by Bugg et al. (1990). *Lygus* spp. typically inhabit the apical portions of host plants, which usually provide airy, warm, sunlit niches, where the bugs feed on nectar, floral structures, developing seeds, and other insects. However, *Lygus* will occupy lower vegetational strata if suitable fruiting structures are available there (Wilson et al. 1984). Among the Fabaceae evaluated here, only the hybrid vetches feature extrafloral nectaries; these occur on the stipules, and are present long before flowering. Extrafloral nectaries have been shown to attract natural enemies that deter herbivores (Koptur 1979, Koptur and Lawton 1988). However, sugar aids survival of *Lygus* nymphs (Butler 1968) and nectariless cotton features lower densities of TPB than do nectaried cultivars (Scott et al. 1988). We observed adult and nymphal TPB feeding at nectaries of the hybrid vetches and the flowers of crimson clover.

Results of the survival and preference experiments do not explain the greater abundances of TPB on hybrid vetches as compared to crimson clover. Nor do phytomass measurements resolve the issue, because they indicate higher fresh and dry readings for crimson clover than for either of the hybrid vetches (S. C. P. unpublished data). We suggest two possible explanations for the discrepancy. Hybrid vetches provide stipular extrafloral nectar long before flowering by either the vetches themselves or by crimson clover, but no nectar is available on crimson clover until flowering in April. Thus, the observed patterns of *Lygus* abundance may be, in part, holdover effects. Another possiblity is that early-instar *Lygus* nymphs survive better on the hybrid vetches than on crimson clover. Hybrid vetches present extrafloral nectar exposed on the plant surface. By contrast, crimson clover is pollinated by bees, and the floral nectar is relatively deeply recessed. Our observations indicate that adult TPB typically probe the flowers of crimson clover directly through the floral aperture, rather than by piercing corollas or calyces. On the other hand, early-instar nymphs have very short proboscises, and may have difficulty obtaining nectar in this way. Our survival trials involved late-instar nymphs and adults, which have longer proboscises, and seem to have little difficulty probing the crimson clover flowers. Our survival trials could not have detected effects on early-instar nymphs. Fleischer and Gaylor (1988) evaluated developmental and survival rates of nymphal TPB caged on potted cotton plants and excised terminals of various wild plants thought to be major hosts. Comparisons revealed few differences, and these were almost entirely restricted to effects on survival of first-instar nymphs. These results may indicate that early-instar nymphal TPB are indeed more sensitive to differences in host-plants than are more fully-developed insects.

Several approaches to vegetational management have been suggested to improve control of *Lygus* spp., including strip mowing of alfalfa (Stern et al. 1967, Stern et al. 1969), preemptive control of roadside weeds that serve as early-season hosts (Fleischer et al. 1989), use of fieldside plantings that either produce few *Lygus* (Fye 1980) or divert them from cash crops (Fleischer and Gaylor 1987), and simple avoidance of leguminous cover crops (Davidson and Lyon 1987, pp. 454-455). The last-named approach seems simplistic and at odds with the need for cover crops to sustain soil fertility. Perhaps the use of cover crops that harbor few *Lygus*, e.g., subterranean clovers, could serve as an alternative approach. The use of subterranean clovers in rotation or as interplants might reduce TPB in agroecosystems; other possible beneficial or deleterious effects should of course be considered. Subterranean clovers occur naturally as far north as southern England, but have been developed principally for the Mediterranean, warm-temperate, and subtropical regions (Duke 1981). Development of additional strains adapted to cool-temperate conditions appears warranted.

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