IMPACT OF INSECT FEEDING AND ECONOMICS OF SELECTED INSECTICIDES ON EARLY SUMMER BERMUDAGRASS SEED PRODUCTION IN THE DESERT SOUTHWEST

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ABSTRACT

Bermudagrass seed yields were significantly increased by use of insecticides which controlled *Trigonotylus tenuis* (Reuter) (Hemiptera: Miridae) and *Chirothrips* spp. (Thysanoptera: Thripidae), although use of methyl-ethyl parathion reduced yields. Seed yield differences among insecticide treatments which controlled thrips (other than methyl-ethyl parathion) were highly correlated with adult *T. tenuis* numbers on last sampling date (14 days) prior to harvest, which reduced seed yield by 22.1 kg/ha (19.7 lbs/acre) per mirid/sweep. High numbers of *T. tenuis* were also highly correlated with reduced numbers of floral spikes, floral spike height and blade height early in crop development. Cypermethrin was not as effective as other insecticides in controlling *T. tenuis* but did control *Toya propinqua* (Fieber) (Homoptera: Delphacidae). *Toya propinqua* levels below 12.8/sweep did not cause sticky seed, and should be considered in future integrated pest management decisions. Increased seed production offset insecticide cost except for the methyl-ethyl parathion treatment. Insecticide cost coupled with value of hay loss due to non-feeding restrictions with certain insecticides is calculated to be uneconomical in fields with yield potential less than 785.3 kg/ha (700 lbs/acre) or when hay price is high. Changing insecticide use patterns and controlling *T. tenuis* could result in potential yield increases of 298.7 kg/ha (266.3 lbs/acre), valued at over $2.0 million per year to bermudagrass seed industry.

INTRODUCTION

Commercial bermudagrass, *Cynodon dactylon* (L.) Pers., seed production is centered in the southwestern United States, primarily in Yuma and La Paz Counties, Arizona, and Riverside and Imperial Counties, California. Historically this area has been fairly small with only 5,260 ha (13,000 acres) in Arizona and 3.64 million kg (8 million lbs) harvested in the US in 1960 (Baltensperger 1961), and approximately 13,355 ha (33,000 acres) grown in the Southwest desert area in 1987.

Two seed harvests are usually obtained during the growing season, one in early summer (late June to mid July) and the other in the fall (October-November). Growers often harvest the hay

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Windrowed subplots were then harvested with a modified John Deere combine and weighed with an Instant-Way hopper feed scale (Arkfeld Co., Norfolk, NE). Harvested subplots were combined only once, although growers usually do this twice for bermudagrass seed. Treatment effects on insect populations for each sample date were analyzed by analysis of variation and means were compared with Duncan's multiple range test, as was seed yield.

The Holtville section of the study was initiated at the University of California Imperial Agricultural Center in June, 1988. Nine insecticide treatments (acephate, carbofuran, disulfoton, esfenvalerate, methomyl, two rates of cypermethrin, two rates of bifenthrin) and an untreated control were replicated four times in a randomized complete block design to evaluate insect control. Plots were 9.1 x 18.2-m (30 x 60 ft). Treatments were applied by ground 13 June and 1 July with 250.6 liters/ha (26.8 GPA) total spray. Plots were sampled 2 and 8 days post 13 June treatment, and 3, 7 and 14 days following the 1 July treatment. Samples consisted of five sweeps with a 38-mm (15 inch) diameter sweep net. Samples were bagged and frozen; insects were later separated and counted. Adults and nymphs were not separated. Plant growth data were collected 30 June. Data were analyzed with ANOVA and Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Biology of pests and beneficials. Adults and nymphs of the planthopper *Toya propinqua* and the mirid *Trigonotylus tenuis* were present in low numbers at study initiation at Roll, as were adult grass thrips. More *T. tenuis* adults than nymphs were found in plots early in the study at Roll. Nymphal numbers were greater than adults on each sample date from 6 June throughout the rest of the study. Adult numbers continued to increase weekly until 21 June at which time plants were drying and seed was hardening. The nymphal peak (19.6/sweep) was also noted on this date. Nymphal populations declined rapidly after 21 June as nymphs were thought to have matured, died from lack of adequate nutrition in drying bermudagrass, and/or oviposition by adults had diminished.

Toya propinqua adults increased in untreated plots throughout the first half of the study period, peaking on 15 June. An increase of almost 6 adults/sweep was detected on the 6 June sample from the prior sample (30 May) when plots were being irrigated, although higher adult populations were noted previously on 27 May than on 30 May. Adults were thought to be migrating into bermudagrass fields during the study from desiccating area vegetation under desert temperatures as nymphal numbers did not support noted increases in adult numbers. Nymph numbers were higher than the adult population in the initial sample but remained below 20/sweep until 15 June. Nymph populations surpassed the adult numbers on 21 June as adult numbers were declining and nymph populations peaked.

Chirothrips populations were similar to that of *T. propinqua* adults as thrips populations increased until 13 June when populations peaked at 5.0/sweep.

Beneficial insects such as the western bigeyed bug, *Geocoris pallens* Stål, *G. atricolor* Montadon, the minute pirate bug, *Orius tristicolor* (White), and *Nabis* spp. were also present throughout this study. Lacewing larvae were occasionally present in samples. *Geocoris* spp. increased throughout the study at Roll, peaking at 3.85/sweep on 27 June. *Orius* populations were very low or not detected the last three sample dates. In comparison beneficial populations at Holtville were much higher during the same time period as were pest populations. Beneficial populations noted were probably in response to host availability, although statistical correlations of beneficials to hosts was not attempted.

Effect of Trigonotylus tenuis feeding. Trigonotylus tenuis caused stunting and delayed bloom of bermudagrass when populations exceeded 77/sweep (Table 1) on 15 June at Holtville. *Trigonotylus* population means from 21 June in bermudagrass plots were more closely negatively correlated with shorter leaf blade means ($P<8 \times 10^{-4}$, $r = -0.88$), fewer floral spikes (straw) after separating the seed. Most insecticide treatments for seed pests are labeled so that treated foliage is not to be used for forage. Bermudagrass so treated with insecticides carrying such labels must be used for other purposes, such as bedding, or destroyed, resulting in lost income for the grower.

Little information has been published concerning the impact of insect damage on bermudagrass seed production; available information deals with the lower yielding fall harvest. Roney (1949) reported that fall bermudagrass seed fields treated with a 2% parathion dust yielded 350-450 lbs of No. 1 seed per acre compared to 30-50 lbs per acre for untreated fields. *Chirothrips mexicanus* Crawford and *C. falsus* Priesner (Thysanoptera: Thripidae) were controlled by 2% parathion dust and reportedly were responsible for seed yield reduction. Several other studies (Byers 1967, Hawkins et al. 1979, Buntin 1988) have investigated insect effects on bermudagrass hay production.

Insect pests of bermudagrass seed currently recognized in Arizona include armyworms, planthoppers, mealybugs, mites, plant bugs, thrips, and whiteflies (Moore et al. 1988). Whiteflies, mealybugs and mites generally are pests associated with fall harvest although they are occasionally pests in the spring. Grass thrips (*Chirothrips* spp.) are reported to be major pests in seed fields every year. Developing seed is attacked in the boot stage and chemical treatments have been applied by growers since 1948 (D. M. Tuttle, personal comm.). Area growers commented prior to study initiation that some untreated fields yielded as much or more than fields treated several times with methyl-ethyl parathion for thrips infestations, and resistance was therefore a concern. Growers were also concerned with a planthopper, *Toya propinqua* (Fieber) (Homoptera: Delphacidae), which can cause seeds to stick together in large clumps due to honeydew production, making harvest and seed cleaning extremely difficult. The planthopper population level resulting in such damage is currently unknown. Growers were not as concerned about *Trigonotylus tenuis* (Reuter) (Hemiptera: Miridae), which has an apparent preference for bermudagrass (Wheeler and Henry 1992) and may well be the most damaging bermudagrass mirid worldwide.

The purposes of this study were to obtain biological information about bermudagrass seed pests during the early summer harvest, evaluate their impact upon seed production, determine the effect of insecticides on beneficial and pest insect populations and resultant seed yields, and assess the economics of insecticide treatments.

MATERIALS AND METHODS

This study consisted of two parts, one being conducted at Roll, AZ, and the other at Holtville, CA. The Roll portion was conducted on a 3-year old field of commercially grown 'Poco Verde', a selected common bermudagrass variety. Five insecticide treatments (carbofuran, acephate, cypermethrin, disulfoton, and methyl-ethyl parathion) were applied in 233.8 liters/ha (25 GPA) spray volumes by a tractor pulled ground sprayer with a 12.9-m (42.5 ft) wide boom. Plot sizes were 25.9 x 396-m (85 x 1300 ft) to reduce insect dispersion between treatments. A randomized complete block design with four replications of each insecticide treatment and the untreated check was utilized. Plots were treated twice (26 May and 14 June 1988).

Samples were taken 1, 4, 11 and 18 days following the first treatment date and 1, 7 and 13 days following the second treatment. Plot centers were sampled using a 0.38-m (15 inch) diameter net. Samples early in the season (1, 4 and 11 days post first treatment) consisted of 50 sweeps per plot due to low insect populations. All subsequent samples consisted of 10 sweeps per plot. Samples were placed in cartons in the field, returned to the laboratory, frozen, and insects were separated by species and stage (adult and nymph) and counted.

Yields were measured at harvest on 11 and 12 July 1988. Subplots measuring 9.3 x 373.2-m (30.5 x 1225 ft) located at plot centers to reduce interplot dispersion effects were windrowed.

($P<2 \times 10^{-4}$, r=-0.92) and shorter floral spikes ($P<6.8 \times 10^{-5}$, r = -0.94) than those from 15 June which were also very highly significantly negatively correlated with the exception of blade height (P<0.003, r = -0.84). *Toya propinqua* numbers (Table 4) were not correlated with plant growth responses.

TABLE 1. Bermudagrass Plant Growth Response to Feeding by Various Population Levels of *Trigonotylus* spp., Holtville, CA, 30 June, 1988.

		Means[a] of blade height, floral spikes and spike height, 30 June, 1988			*Trigonotylus*/ sweep	
Treatment	Lb. (AI) per acre	Blade height (mm)	Floral spikes/ 0.11 m^2	Spike height (mm)	15 June	21 June
Acephate 75S	0.8	13.6 ^{D}	192 ^{C}	17.2^{B}	0.8	34.4
Bifenthrin 2E	0.08	13.2^{BCD}	146^{BC}	17.0^{B}	0.8	24.6
Bifenthrin 2E	0.12	13.9 ^{D}	209 ^{C}	17.8^{B}	0.2	23.6
Carbofuran 4F	1.0	14.0 ^{D}	146^{BC}	18.2^{B}	1.0	22.4
Cypermethrin 2.5E	0.1	12.2^{AB}	42^{A}	14.6^{A}	105.8	252.2
Cypermethrin 2.5E	0.15	12.4^{ABC}	58^{A}	14.2^{A}	79.4	189.4
Disulfoton 8E	1.0	14.0 ^{D}	148^{BC}	17.5^{B}	2.0	46.0
Esfenvalerate 0.66E	0.025	11.8^{A}	79^{AB}	14.8^{A}	90.4	167.8
Methomyl 1.8L	1.0	13.5 ^{CD}	162 ^{C}	17.1^{A}	3.6	100.0
Untreated Check	----	12.4^{ABC}	63^{A}	14.9^{A}	164.4	191.2

[a]Means in columns followed by same letter are not significantly different at the $p \leq 0.05$ level (Duncan's MRT).

Mean floral plant spike heights averaged 17.5 cm and 14.6 cm between treatments where *T. tenuis* were controlled (bifenthrin, methomyl, acephate, disulfoton) and not adequately controlled, respectively, a 16.3% reduction (Table 1). Blade height was also reduced by 10.4% between treatments where *T. tenuis* was controlled (13.7-mm) and uncontrolled (12.2 mm). Mean number of floral spikes per 0.11-m^2 were reduced by 63.8% when comparing *T. tenuis* controlled treatments (167.2 spikes/0.11-m^2) with treatments not providing control (60.5 spikes/0.11-m^2). Reductions in plant height and blade measurements may also represent an approximately equal percentage reduction in hay/straw yield. Buntin (1988), in a greenhouse study, found that *T. tenuis* Reuter (as *T. doddi*) adults fed on leaves, leaf whorls and stems of a vegetative coastal bermudagrass in Georgia, resulting in leaf chlorosis and severe stem stunting. Two adults per cage reduced stem height by 28.0% and plant dry weight by 31.7%; four adults per cage reduced stem height by 55.6% and plant dry weight by 56.7%. Dry matter production continued to decrease as adult density increased (Buntin 1988). Wheeler and Henry (1985) found that *T. caelestialium* (Kirkaldy) feeding on seedling oats caused extensive chlorosis and browning, and one *T. caelestialium*/oat seedling reduced growth by 73.6% compared to the check at 15 days post insect introduction.

Insecticide Efficacy. Chirothrips spp. at Holtville (Table 2) were initially controlled by both rates of cypermethrin, methomyl and the high rate of bifenthrin. On 21 June, *Chirothrips* populations increased from the previous sample, and greater than 50% control was noted with the high rate of cypermethrin, methomyl, carbofuran and disulfoton. On 4 July (3 days after second application), treatments providing greater than 50% control (methomyl, both rates of cypermethrin, and esfenvalerate) were similar to the 15 June sample. Only carbofuran (3.25/sweep) and acephate (4.4/sweep) provided greater than 50% thrips control compared with the check on 8 July. Control from all treatments was not evident by 15 July.

At Roll, where the experiment commenced earlier in the year, carbofuran provided the best control until the last sampling date (27 June). Methyl-ethyl parathion provided little control of *Chirothrips* spp. (Fig. 1) based on reduction noted one day after the second application (14 June) in comparison to the untreated check. Treatments other than methyl-ethyl parathion provided acceptable control of *Chirothrips*.

Trigonotylus tenuis was controlled by carbofuran, acephate, bifenthrin and disulfoton at Holtville after the 13 June treatment, followed by methomyl. The increase in *T. tenuis* population noted in methomyl plots from 15 to 21 June apparently was the result of adult *T. tenuis* dispersion into plots and short residual of material. This same pattern was repeated following the second application. Cypermethrin and esfenvalerate treatments were not effective against *T. tenuis* compared with other insecticides (Table 3).

At Roll, carbofuran provided excellent control of *T. tenuis* nymphs throughout the study followed closely by acephate. Methyl-ethyl parathion reduced nymphal and adult populations following the second application on 14 June (Fig. 2) although adult populations were soon increased by dispersion into these plots. Cypermethrin did provide control following the 14 June treatment, but populations of adults and nymphs were not controlled to as low of levels as provided by the other insecticides. Acephate resulted in fewer adult *T. tenuis* the first two sample dates following the 14 June treatment than did other insecticides.

TABLE 2. Mean[a] Number *Chirothrips* per Sweep at Holtville, CA, 1988.

Treatment	Lb. (AI)/ acre	Treated 13 June		Treated 1 July		
		15 June	21 June	4 July	8 July	15 July
Acephate 75S	0.8	2.0^{ABC}	7.1^{ABC}	6.4^{A}	4.4^{A}	6.2^{A}
Bifenthrin 2E	0.08	2.3^{ABC}	15.3^{A}	3.4^{A}	7.4^{A}	8.0^{A}
Bifenthrin 2E	0.12	0.8^{C}	8.7^{ABC}	6.0^{A}	8.5^{A}	10.2^{A}
Carbofuran 4F	1.0	2.1^{ABC}	5.4^{BC}	2.4^{A}	3.2^{A}	7.3^{A}
Cypermethrin 2.5E	0.1	1.0^{BC}	5.7^{BC}	1.7^{AB}	5.1^{A}	8.5^{A}
Cypermethrin 2.5E	0.15	1.8^{ABC}	2.4^{C}	0.9^{B}	8.5^{A}	6.3^{A}
Disulfoton 8E	1.0	3.8^{ABC}	6.0^{BC}	2.6^{A}	5.9^{A}	9.7^{A}
Esfenvalerate 0.66E	0.025	4.4^{AB}	10.5^{ABC}	1.9^{AB}	8.0^{A}	7.9^{A}
Methomyl 1.8L	1.0	1.7^{ABC}	5.3^{BC}	1.9^{AB}	10.7^{A}	5.0^{A}
Untreated Check	----	7.0^{A}	11.6^{AB}	4.0^{A}	8.8^{A}	7.0^{A}

[a]Means in columns followed by the same letter are not significantly different at the $P<0.05$ level (15 June = $P<0.01$ level). Square root transformation applied to 15 June and 4 July data for analysis.

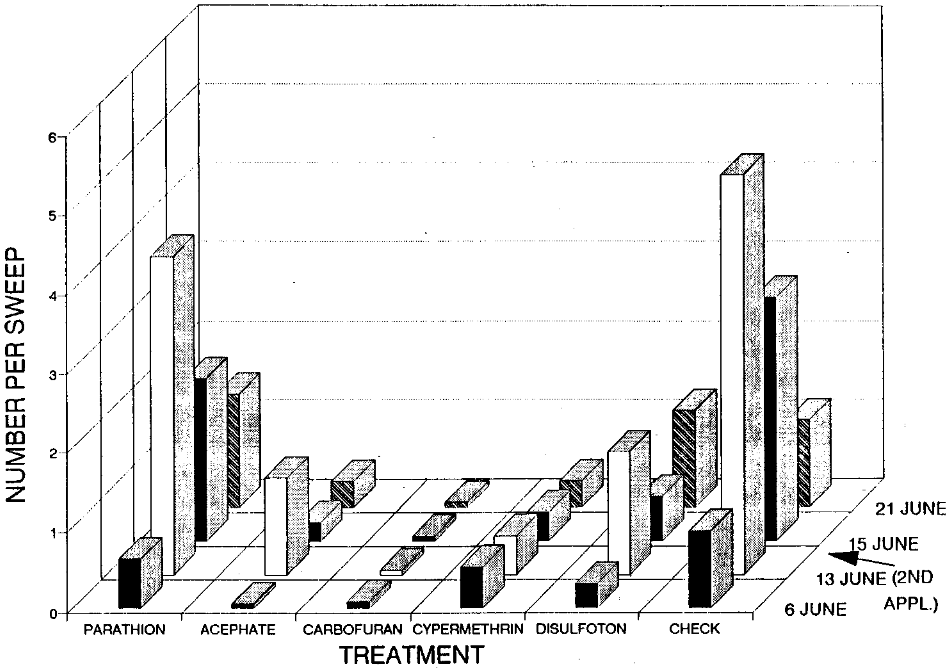

Fig. 1. Mean number of adult *Chirothrips* spp. in bermudagrass following insecticide treatments on 26 May and 14 June 1988 at Roll, AZ.

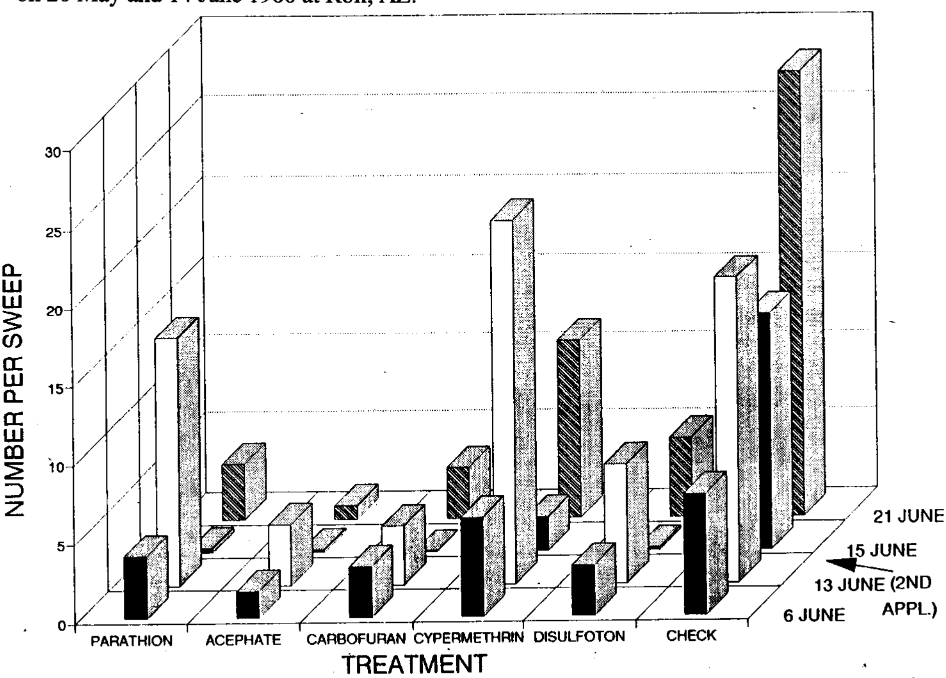

Fig. 2. Mean number (adults and nymphs) of mirid plant bug *Trigonotylus tenuis* (Reuter) in bermudagrass following insecticide treatments on 26 May and 14 June 1988 at Roll, AZ.

TABLE 3. Mean Number *Trigonotylus tenuis* per Sweep at Holtville, CA, 1988

Treatment	Lb. (AI)/ acre	Treated 13 June		Treated 1 July		
		15 June	21 June[a]	4 July[b]	8 July[b]	15 July[a]
Acephate 75S	0.8	0.8 C	34.4 D	0.8 C	4.2 B	3.0 B
Bifenthrin 2E	0.08	0.8 C	24.6 D	0.2 C	6.6 AB	4.8 B
Bifenthrin 2E	0.12	0.2 C	23.6 D	0.6 C	4.4 B	5.2 B
Carbofuran 4F	1.0	1.0 C	22.4 D	3.6 C	9.2 AB	13.8 AB
Cypermethrin 2.5E	0.1	105.8 A	252.2 A	44.6 A	22.0 A	19.2 AB
Cypermethrin 2.5E	0.15	79.4 B	189.4 AB	35.2 AB	16.6 A	14.8 AB
Disulfoton 8E	1.0	2.0 C	46.0 D	2.2 C	8.0 AB	5.2 B
Esfenvalerate 0.66E	0.025	90.4 B	167.8 B	13.8 ABC	10.8 AB	10.8 AB
Methomyl 1.8L	1.0	3.6 C	100.0 C	4.0 BC	9.6 AB	36.2 A
Untreated Check	----	164.4 A	191.2 AB	6.2 ABC	8.2 AB	12.6 AB

[a]Square root transformation applied to original data for analysis, actual means reported.
[b]Log transformation applied to original data for analysis, actual means reported.

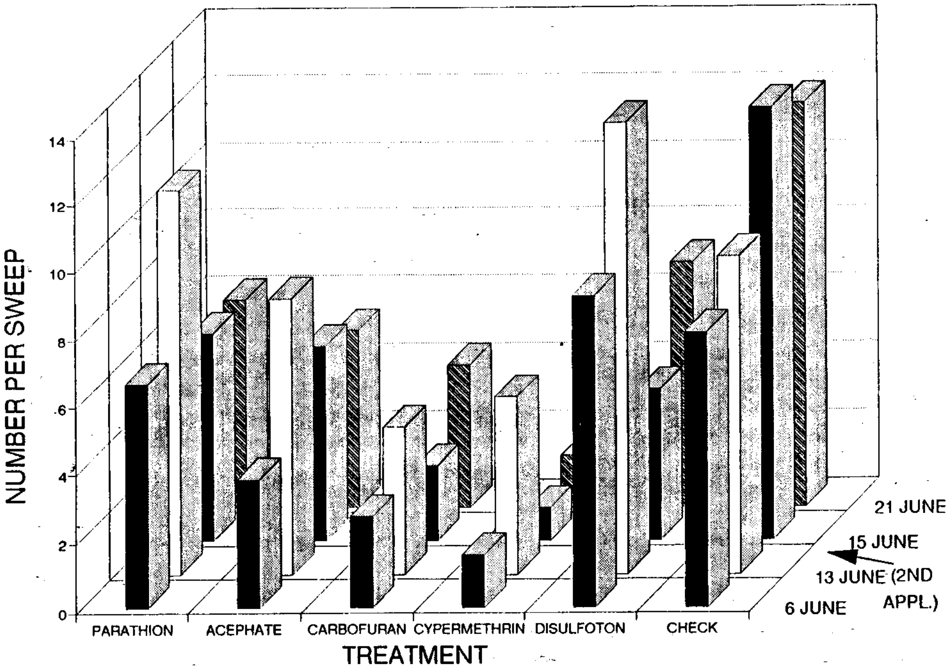

Fig. 3. Mean populations (adults and nymphs) of delphacid planthopper *Toya propinqua* (Fieber) in bermudagrass following insecticide treatments on 26 May and 14 June 1988 at Roll, AZ.

The high rate of cypermethrin was the most effective against *Toya propinqua* populations (Table 4) at Holtville the first two sample dates, and cypermethrin had the fewest numbers of adults at Roll on 6 June. All insecticides significantly reduced total (adult + nymph) planthopper populations at Holtville the first sample date, but all treatments had less than 50% control by 21 June. Following the second treatment at Holtville, population means were significantly lower in bifenthrin and carbofuran treatments compared to other treatments.

Over the entire experiment at Roll, the cypermethrin treatment had fewer adult *T. propinqua* than did other treatments although the carbofuran treatment had fewer adults on one sample date (13 June). Following the second application, adult *T. propinqua* numbers were higher in acephate and methyl-ethyl parathion treatments than in other insecticide treatments (Fig. 3).

TABLE 4. Mean Number *Toya propinqua* per Sweep at Holtville, CA, 1988.

Treatment	Lb. (AI)/ acre	Treated 13 June		Treated 1 July		
		15 June	21 June	4 July[a]	8 July[a]	15 July
Acephate 75S	0.8	85.8 CD	207.8 ABC	146.8 A	149.6 A	58.0 A
Bifenthrin 2E	0.08	107.2 CD	212.4 ABC	57.8 B	71.6 B	45.0 A
Bifenthrin 2E	0.12	95.6 CD	215.6 ABC	77.0 AB	56.8 B	35.0 AB
Carbofuran 4F	1.0	132.4 BC	180.6 AB	74.4 AB	47.6 B	13.6 B
Cypermethrin 2.5E	0.1	93.0 CD	222.4 ABC	96.9 AB	173.6 A	32.2 AB
Cypermethrin 2.5E	0.15	76.6 D	167.4 C	79.2 AB	127.0 A	31.2 AB
Disulfoton 8E	1.0	97.4 CD	235.8 ABC	104.8 A	137.2 A	49.8 A
Esfenvalerate 0.66E	0.025	178.6 B	282.4 A	91.6 AB	130.8 A	33.6 AB
Methomyl 1.8L	1.0	163.8 B	276.2 A	133.0 A	165.6 A	60.0 A
Untreated Check	----	286.2 A	250.8 AB	92.6 AB	129.2 A	47.2 A

[a]Square root transformation applied to original data for analysis, actual means reported. Means in columns followed by the same letter are not significantly different at the $P \leq 0.05$ level except for 15 July ($P <= 0.01$)

Among beneficial insects, damsel bugs (*Nabis* spp.) were significantly reduced at Holtville by all insecticide treatments except disulfoton two days post treatment (Table 5). *Nabis* populations on 21 July were lowest as a result of carbofuran and bifenthrin treatments, followed by acephate and cypermethrin treatments. Differences between treatments following the second application did not follow the same pattern, perhaps due to host availability. *Nabis* were not prevalent at the Roll site.

Orius sp. were not statistically different from the untreated check at any time in the study at Holtville. Fewer *Orius* were noted in treatments of carbofuran, cypermethrin, and bifenthrin on 21 June (Table 6). At Roll, significantly fewer *Orius* were noted for all treatments other than methyl-ethyl parathion on 30 May.

At Roll, 85% of the *Geocoris* were western bigeyed bug (*G. pallens* Stål) and 15% *G. atricolor* Montandon. Significant differences between treatments were not noted until 11 days (6 June) after treatment when *Geocoris* population in the acephate treatment (0.05/sweep) was significantly less than the untreated check (1.26/sweep). Significantly fewer *Geocoris* were

TABLE 5. Mean Number *Nabis* per Sweep at Holtville, CA, 1988.

Treatment	Lb. (AI)/ acre	Treated 13 June		Treated 1 July		
		15 June	21 June[a]	4 July[b]	8 July[a]	15 July[a]
Acephate 75S	0.8	0.1 B	0.6 DE	2.2 AB	0.7 BC	0.5 B
Bifenthrin 2E	0.08	0.2 B	0.3 E	0.3 BC	1.0 BC	0.1 B
Bifenthrin 2E	0.12	0.1 B	0.1 E	0.3 BC	0.7 C	0.4 B
Carbofuran 4F	1.0	0.0 B	0.1 E	0.3 BC	1.0 BC	0.6 B
Cypermethrin 2.5E	0.1	0.2 B	0.8 DE	0.6 ABC	1.9 ABC	1.1 AB
Cypermethrin 2.5E	0.15	0.4 B	0.9 DE	0.1 C	2.2 ABC	0.4 B
Disulfoton 8E	1.0	2.2 A	5.2 B	0.3 BC	1.4 ABC	1.6 A
Esfenvalerate 0.66E	0.025	0.3 B	3.2 BC	1.4 ABC	5.6 A	1.0 AB
Methomyl 1.8L	1.0	0.1 B	1.4 CD	2.0 AB	3.3 AB	1.0 AB
Untreated Check	----	3.6 A	11.3 A	2.2 AB	3.1 ABC	0.9 AB

[a] Square root transformation applied to original data for analysis, actual means reported.
[b] Log transformation applied to original data for analysis, actual means reported. Means in columns followed by the same letter are not significantly different at the $P \leq 0.05$ level ($P \leq 0.01$ for 15 and 21 June, 15 July).

TABLE 6. Mean[a] Number *Orius* per 5 Sweeps at Holtville, CA, 1988.

Treatment	Lb. (AI)/ acre	Treated 13 June		Treated 1 July		
		15 June	21 June	4 July	8 July	15 July
Acephate 75S	0.8	1.00 A	22.0 ABCD	2.75 A	0.25 A	0.75 A
Bifenthrin 2E	0.08	0.75 A	15.25 CD	3.25 A	1.0 A	2.25 A
Bifenthrin 2E	0.12	0.5 A	17.25 BCD	5.0 A	0.25 A	0.75 A
Carbofuran 4F	1.0	0.5 A	10.75 D	0.25 A	0.25 A	2.0 A
Cypermethrin 2.5E	0.1	0.5 A	10.25 A	0.5 A	1.5 A	1.75 A
Cypermethrin 2.5E	0.15	1.75 A	11.25 A	0.25 A	1.5 A	0.5 A
Disulfoton 8E	1.0	1.0 A	27.5 AB	3.25 A	0.0 A	1.0 A
Esfenvalerate 0.66E	0.025	2.75 A	20.5 ABCD	4.5 A	0.75 A	1.75 A
Methomyl 1.8L	1.0	1.0 A	29.0 A	1.75 A	1.25 A	0.5 A
Untreated Check	----	2.25 A	21.0 ABCD	1.5 A	1.0 A	0.75 A

[a]Means in columns followed by the same letter are not significantly different at the $P \leq 0.05$ level.

present the next sample date (13 June) in acephate treated plots compared with untreated and disulfoton treatments. Statistically significant differences were noted for all treatments one day (15 June) after the second application. All treatments other than disulfoton had statistically fewer *Geocoris* on 21 June but no significant differences existed on the final sample date.

Geocoris spp. populations were initially significantly reduced by all treatments except for methomyl and disulfoton at Holtville, and were highest in the untreated followed by methomyl on 15 and 21 June. Following second application (1 July), *Geocoris* spp. were highest in methomyl plots until the final sample. Statistical differences noted between treatments in samples from 8 and 15 July are the result of insecticide coupled with host availability (Table 7).

TABLE 7. Mean[a] Number *Geocoris* per Sweep at Holtville, CA, 1988.

Treatment	Lb. (AI)/ acre	Treated 13 June		Treated 1 July		
		15 June[b]	21 June[b]	4 July[b]	8 July	15 July[b]
Acephate 75S	0.8	0.2 [C]	1.2 [D]	0.2 [D]	4.7 [D]	1.8 [D]
Bifenthrin 2E	0.08	0.3 [BC]	0.5 [D]	1.0 [CD]	9.5 [BCD]	13.2 [ABC]
Bifenthrin 2E	0.12	0.3 [BC]	0.4 [D]	0.2 [D]	5.2 [CD]	6.0 [CD]
Carbofuran 4F	1.0	0.6 [BC]	1.9 [CD]	0.7 [CD]	7.4 [BCD]	7.3 [CD]
Cypermethrin 2.5E	0.1	0.4 [BC]	4.8 [BC]	1.4 [AB]	14.4 [AB]	33.0 [A]
Cypermethrin 2.5E	0.15	0.7 [BC]	3.8 [BC]	1.3 [BCD]	8.4 [BCD]	12.2 [ABC]
Disulfoton 8E	1.0	0.9 [AB]	4.2 [BC]	0.9 [CD]	13.4 [ABC]	11.5 [BCD]
Esfenvalerate 0.66E	0.025	0.6 [BC]	5.9 [AB]	1.4 [AB]	11.8 [ABCD]	23.7 [AB]
Methomyl 1.8L	1.0	1.8 [A]	7.3 [AB]	3.4 [A]	18.1 [A]	26.7 [AB]
Untreated Check	----	1.9 [A]	10.9 [A]	2.0 [AB]	8.8 [BCD]	13.4 [ABC]

[a] Means in columns followed by same letter are not significantly different at the $P \leq 0.05$ level (Duncan's MRT).
[b] Square root transformation applied to original data for analysis, actual means reported.

Effect of Toya propinqua feeding. Toya propinqua numbers at Roll did not cause sticky seed. Peak populations of planthoppers (adults and nymphs) at Roll reached only 12.8/sweep on 15 June. Yield differences at Roll were not attributed to planthopper numbers. *Toya propinqua* numbers at Holtville reached 286/sweep in the untreated check (Table 4) but were not correlated with any detrimental plant effects. On young barley plants, *T. propinqua* adults feed primarily on sheaths and less on stems and cause considerable injury if transferred to seedling barley plants (Raatikainen and Vasarainen 1990), but does not feed directly on developing seed. Large numbers of planthoppers could reduce potential yields (seed and forage) as well as cause sticky seed. Byers (1967) found that effective materials resulting in large differences in leafhopper populations on bermudagrass did not result in differences in forage yield, although *T. propinqua* was not noted as present. *Toya propinqua* populations large enough to cause enough plant stress resulting in seed yield reduction would probably also result in sticky seed.

Toya propinqua is known to vector the bermudagrass disease Cynodon chlorotic streak virus (CCSV), caused by a rhabdovirus, to bermudagrass and maize, and barley yellow striate mosaic virus (Lockhart et al. 1985a). Bermudagrass diseases also include barley yellow dwarf virus and bermudagrass etched-line virus (BELV) (Lockhart et al. 1985b), and a mycoplasmic organism (MLO) thought to cause bermudagrass yellow leaf disease (Bar-Joseph et al. 1975). *Toya propinqua* does not vector BELV (Lockhart et al. 1985b) but a related planthopper, *T. catalina* (Fennah), vectors African cereal streak virus (Harder and Bakker 1973), and the potential exists for *T. propinqua* to vector related diseases as it feeds on various grasses such as maize, barley, rice, etc. (Wilson and O'Brien 1987). *Toya propinqua* is not presently of economic importance as a vector of CCSV in the desert Southwest, but it may become so in the future.

Seed yields. Use of methyl-ethyl parathion resulted in significantly less seed yield compared with other insecticides (Table 8). This may have been due to a phytotoxic effect of methyl parathion on bermudagrass which causes lower production as noted in other crops such as cotton (Youngman et al. 1990). Two applications of methyl-ethyl parathion 6-3 EC at a rate of 4.7 liters product/ha (2 qts/acre/application) in a 1989 trial resulted in a 13.0% seed yield reduction (103.0 lbs/acre or 115.5 kg/ha) but there was no significant difference in straw production. Season long insect records were not available (Tickes, unpublished data). All other insecticide treatments economically increased seed yields compared to the untreated check (Table 8) although no statistical differences existed for seed yield between these treatments and the untreated check. Increased seed yields following treatment with acephate were followed by treatments with disulfoton, carbofuran and cypermethrin, respectively. Slightly higher yields were obtained from disulfoton than carbofuran treated plots although the disulfoton plots had more thrips, planthoppers and mirids during the season. Lower yields in the untreated check compared to the higher yielding treated plots were attributed primarily to *Chirothrips* spp. feeding. Although a high of only 5.0 *Chirothrips*/sweep was detected in untreated plots, this was 46.5-99.9% more than in insecticide treatments other than methyl-ethyl parathion. The untreated check had fewer *T. tenuis*/sweep than the cypermethrin treatment on 13 June, but seed yield was 119.2 kg/ha (133.8 lbs/acre) greater in the cypermethrin treatment due to *Chirothrips* control and early season reduction of *T. tenuis,* although cypermethrin is weak against *T. tenuis*.

Correlations were performed on seed yields from insecticide treatments that controlled thrips and *T. tenuis* numbers. The untreated check was not included since *Chirothrips* spp. and *T. tenuis* were not controlled, affecting yield; methyl-ethyl parathion treatment was not included due to significant yield loss attributed to use of this material. Seed yields in the plots of the four insecticide treatments were highly correlated ($P \leq 0.006$, $r = -0.65$) with adult *T. tenuis* numbers from the last sample (27 June). *Trigonotylus tenuis* nymphs were not statistically correlated with seed yield reductions, nor was total (adult plus nymph) population on this sample date. The seed yield reduction at low levels of *T. tenuis* infestations was calculated to be 22.1 kg/ha (19.7 lbs/acre) for each adult mirid/sweep. Numbers of *T. tenuis* at previous sampling dates were not correlated with significant reductions in seed yield. Natwick (unpublished data), in a 1989 experiment, also demonstrated a negative correlation between the log of *Trigonotylus* population during mid-July following 6 July treatment and seed yield when fall harvested. *Trigonotylus* numbers were most closely correlated on 10 July ($P \leq 0.003$, $r = -0.86$) than 14 and 18 July, which were also significant. The reduction noted is probably due to *Trigonotylus* feeding on vegetative parts as direct feeding on developing seeds would not have been possible until later in crop development.

Although most previous reports of *Trigonotylus* feeding are in association with vegetative plant parts, some *Trigonotylus* spp. have been suspected to inflict considerable damage to cereal crop heads as large numbers of *T. caelestialium* were observed on wheat heads and partially green stems just beneath these heads (Wheeler and Henry 1985). Vilkova (1976) noted that the optimal feeding conditions of mirid plant bugs on wheat were restricted to the short period of grain formation and only to some parts of the grain as the mouthparts are not adequate to overcome hard mechanical barriers. *Trigonotylus tenuis* feeding on maturing seeds would not have been possible at early stages of this study as seeds would have only been in floral stages, although feeding by *Trigonotylus* spp. on developing seeds would have occurred when they became available (Miklailova 1981, Blinn and Yonke 1986, Vilkova 1976, Wheeler and Henry 1985). Differences noted between the Holtville and Roll study sites may have been due to differences in study initiation (May vs. June) and crop development resulting in different bermudagrass maturity stages on the same date at the two study sites.

Economics. Insecticides which increased seed yield in this study were economically justified, although use of methyl-ethyl parathion decreased seed yields and is considered uneconomical. If income from straw sales are included, although not currently labeled for such, the same insecticide treatments were even more economical (Table 8). The acephate treatment was the most cost effective, followed by the other systemic insecticides.

Treatments may not be economically justified every year for each bermudagrass seed field. The key factors that govern such decisions for insects causing a percentage loss is the yield potential of the field as well as the price and quantity of hay that will be available. The actual seed yield loss is less from lower yielding fields than from higher yielding fields when percent loss is the same. The 14.3% seed yield loss noted for the untreated check from insect pressures compared to an average of the four insecticide treatments (other than ethyl-methyl parathion) would not have been economically justified for any treatment if yield potential for this field been only 785.3 kg/ha (700 lbs/acre) and the straw was unable to be sold due to feeding restrictions of the insecticides. If the price of bermudagrass straw had been higher at the time of this study, the cypermethrin treatment would not have been economical. However, the same treatment would be expected to be economical when higher numbers of thrips are noted than in this experiment as more seed loss would occur.

CONCLUSION

Usage of methyl-ethyl parathion in this experiment resulted in seed yield loss due to suspected phytotoxicity. Methyl-ethyl parathion provided little control of *Chirothrips* so insecticide resistance to this compound may be a contributing factor of prior experienced lowered yields, although lower yields were primarily attributed to detrimental plant effects associated with this material. A shift in insecticide use pattern from methyl-ethyl parathion (commonly used by the growers because of lack of feeding restrictions) to a systemic insecticide such as acephate could change economic returns by approximately $336/ha ($136/acre). Assuming 50% of the 33,000 acres currently in production will respond economically in like manner, this represents an increased annual return of over $2.2 million in seed production.

The relationship between *Chirothrips* numbers and yield reduction is still unknown but *Chirothrips* damage was thought to be much less substantial in the untreated plots than damage by the mirid, *T. tenuis*. We were unable to determine the yield effect of *Trigonotylus* feeding early in plant development on yield when *Chirothrips* are also present since treated plots, with the exception of methyl-ethyl parathion, yielded at least 149 kg/ha (133 lbs./acre) more seed than the untreated control. One difficulty in collecting thrips numbers may have been due to the sampling of thrips populations by sweep net. Although this sample technique was indicative of thrips relative abundance, growers and professional crop advisors do not use this method for determining thrips populations. The method of beating developing seed heads against a surface such as a hand and counting the thrips is currently utilized due to time requirements of sample sorting. The relationship between the two sample methods is presently unclear.

Trigonotylus tenuis was found to reduce bermudagrass seed yields, which has not been demonstrated previously. Mean seed yield reductions of 22.1 kg/ha (19.7 lbs/acre) were noted for each *T. tenuis*/sweep with low populations on the 26 June sampling date. High populations

TABLE 8. Economics of Bermudagrass Seed Yields and Net Return at Roll, AZ, 1988.

Treatment	Seed yield[a] (lbs/acre)	Insecticide cost ($ per acre x 2 treatments)[b]	Net return at $1.00/lb of unhulled seed	Expected[c] yield (Hay straw tonnage per acre)	Gross return ($/acre) @ $27.50/ton hay straw		Net $/acre vs. untreated check +(-)	
					Without hay straw	With hay straw[e]	Without hay straw	With hay straw
Methyl-Ethyl Parathion 6-3	956.8 [B]	10.41	946.39	4.25	1,063.26	1,063.26	(54.46)	(54.46)
Acephate 75S	1,223.1[A]	23.95	1,199.15	4.25	1,199.15[d]	1,316.02	81.42	198.30
Carbofuran 4F	1,187.6[A]	30.96	1,156.64	4.25	1,156.64[d]	1,273.51	38.92	155.79
Cypermethrin 3E	1,153.7[A]	31.43	1,122.27	3.55	1,122.27[d]	1,220.09	4.55	102.37
Disulfoton 8F	1,195.1[A]	15.95	1,179.15	4.25	1,179.15[d]	1,296.02	61.43	178.30
Untreated check	1,019.9[AB]		1,029.90	3.55	1,117.72	1,117.72		

[a] Means in columns followed by the same letter are not significantly different at the $P \leq 0.05$ level.
[b] Average price for material in area at time of application and includes application cost of $2.00/acre/application.
[c] Estimated reduction in straw yields by 17% in some treatments due to feeding of *Trigonotylus tenuis*.
[d] Straw not able to be sold for feed due to insecticide restrictions.
[e] Straw sold for purposes other than for feed but assumes same price/ton.

caused stunting and delayed bloom and resulted in narrower leaf blades and fewer and significantly shorter floral spikes. Mean floral plant spike height was also reduced by 16.3% and blade height was reduced by 10.4%. Mean number of floral spikes per 0.11 m^2 were reduced by 63.8%. We are not aware of any other data demonstrating *T. tenuis* damage to early summer bermudagrass seed production.

Toya propinqua had little, if any, effect on seed yield in comparison to thrips and mirids. The planthopper population level which can cause sticky seed is still unknown. Treatments for planthoppers should only be made when populations are large enough to cause sticky seed as yield reductions from this pest were not noted. Population levels of 12.8/sweep did not cause sticky seed and should be considered in future pest management decisions. Attention to diseases vectored by this pest is advised.

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