Peanut Fungicides: Effect on Survival and Development of the Corn Earworm, Fall Armyworm, and Velvetbean Caterpillar[1]

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ABSTRACT

The fungicides chlorothalonil, tebuconazole, and propiconazole commonly used for control of peanut diseases were evaluated for activity against the corn earworm [*Helicoverpa zea* (Boddie)], fall armyworm [*Spodoptera frugiperda* (J. E. Smith)], and velvetbean caterpillar (*Anticarsia gemmatalis* Hübner). Chlorothalonil most adversely affected early establishment and survival of neonates of all three insect species on peanut terminal buds. Chlorothalonil also decreased the weight of larvae of all three species at 10 d and extended the time to pupation for fall armyworm and velvetbean caterpillar larvae. Similarly, tebuconazole adversely affected early survival and establishment, decreased 10-d weight and extended time to pupation of corn earworm and velvetbean caterpillar larvae, but had little effect on fall armyworm larvae. Propiconazole had no effect on establishment and survival of corn earworm and fall armyworm larvae on peanut terminals, and actually increased the weight of 10-d-old larvae for all three insects over that recorded for the untreated control. Orthogonal comparisons of the activity of five chlorothalonil-based fungicides against the fall armyworm showed that the activity was due to chlorothalonil rather than to formulation. At equivalent concentrations used in the field, Bravo Ultrex® was significantly more active against larvae of the fall armyworm than was a comparable concentration of Bravo 720®. However, regression lines did not differ for the two fungicides for any of the developmental parameters measured when larvae of all three species were fed different concentrations of Bravo 720® and Bravo Ultrex® in their meridic diet.

Key Words: *Arachis hypogaea*, *Helicoverpa zea*, *Spodoptera frugiperda*, *Anticarsia gemmatalis*.

Peanut, *Arachis hypogaea* L., is a high value crop that requires extensive use of pesticides for profitable production. Peanut production in the U.S. requires a relatively long growing season (130-170 d) and, thus, is concentrated in the more southern states. The climate of this region is conducive to plant diseases such as early leaf spot (*Cercospora arachidicola* Hori), late leaf spot [*Cercosporidium personatum* (Berk. & Curt.)], southern stem rot (*Sclerotium rolfsii* Sacc.), etc., and insect pests such as lesser cornstalk borer [*Elasmopalpus lignosellus* (Zeller)], corn earworm [*Helicoverpa zea* (Boddie)], potato leafhopper (*Empoasca fabae* Harris), etc.

Pesticides applied for control of one group of pests may directly or indirectly affect another group. As examples, the insecticides carbaryl, methomyl, monocrotophos, and toxaphene and the herbicide dinoseb plus alachlor are highly toxic to the striped earwig [*Labidura riparia* (Pallas)] (de Rivero and Poe, 1981); the insecticide chlorpyrifos reduces incidence of southern stem rot (Csinos, 1985; Chapin and Thomas, 1993) and, when applied for control of the lesser cornstalk borer, reduces the number of predators and increases the number of corn earworm larvae (Funderburk *et al.*, 1990); and some fungicides, especially when tank mixed with insecticides, may enhance outbreaks of the twospotted spidermite (*Tetranychus urticae* Koch) (Campbell, 1978). Therefore, knowledge of the effect of new pesticides on nontarget organisms in the peanut agroecosystem is important for the development of a holistic approach to peanut pest management.

For over 20 yr, chlorothalonil has been used extensively to control both early and late leaf spot on peanut. Recently, the sterol-inhibiting fungicides propiconazole and tebuconazole were registered for use on peanuts in the U.S. These fungicides are active against both foliar and soil-borne diseases of peanut (Brenneman and Sumner, 1989; Brenneman and Murphy, 1991; Brenneman *et al.*, 1991, 1994; Brenneman and Culbreath, 1994; Culbreath *et al.*, 1995). The objective of this investigation was to evaluate the fungicides propiconazole, tebuconazole, chlorothalonil, and mixtures of chlorothalonil with propiconazole or tebuconazole for activity against the corn earworm (CEW), fall armyworm (FAW) [*Spodoptera frugiperda* (J. E. Smith)], and the velvetbean caterpillar (VBC) (*Anticarsia gemmatalis*

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Hübner). Several different chlorothalonil formulations also were evaluated for activity against these insects.

Materials and Methods

Laboratory studies were conducted to evaluate the influence of fungicides currently used for disease control in peanut for activity against foliage-feeding insect pests of peanut. The CEW, FAW, and VBC colonies used in this study were maintained at the Insect Biology and Population Management Research Laboratory, Tifton, GA, as described by Perkins *et al.* (1973), Perkins (1979) and Greene *et al.* (1976), respectively.

Two types of bioassays were conducted, feeding insects peanut foliage that had been immersed in a water suspension of the fungicide, and incorporating the fungicides into the meridic diet of the insect. For the foliage bioassays, certified cv. Florunner seed were planted in Tifton loamy sand (fine, loamy, siliceous, thermic Plinthic Paleudults) at *ca.* 120 kg of seed/ha in two-row plots on a 1.83-m bed with 81 cm between rows. Before planting, the field was treated with benefin (1.8 kg ai/ha) + imazethapyr (0.076 kg ai/ha). Before plant emergence the field was treated with metolachlor (2.4 kg ai/ha) + paraquat (0.15 kg ai/ha) + bentazon (0.6 kg ai/ha). Tests were initiated *ca.* 40 d after plant emergence. Plants were not treated with fungicide to control leaf spots prior to or during the time that laboratory bioassays were conducted.

Terminal buds were removed from peanut plants in the field, placed in a Ziplock® bag, and taken to the laboratory for assay. Tests 1 through 3 evaluated survival and development of CEW, FAW, and VBC larvae, respectively, on terminal buds treated as follows: (a) an untreated control, (b) chlorothalonil (Bravo 720®) at 3.13 mL/L H_2O (0.84 kg ai/ha), (c) chlorothalonil (Bravo 720®) at 4.69 mL/L H_2O (1.13 kg ai/ha), (d) tebuconazole (Folicur 3.6 F®) at 1.41 mL/L H_2O (0.23 kg ai/ha), (e) chlorothalonil (Bravo 720®) at 3.13 mL/L H_2O + tebuconazole at 1.41 mL/L H_2O, (f) propiconazole (Tilt 3.6 EC®) at 0.78 mL/L H_2O (0.13 kg ai/ha), and (g) chlorothalonil (Bravo 720®) at 3.13 mL/L H_2O + propiconazole at 0.78 mL/L H_2O. All fungicide rates were equivalent to their field application in 374.1 L H_2O/ha (=40 gal H_2O/Ac). Peanut terminal buds were placed in a wire basket, immersed in a solution of the appropriate treatment for 1 min, placed on a paper towel, and allowed to air dry. Untreated terminals were immersed in water for 1 min. Three to six terminal buds, depending on the stage of development of the insect, were placed in an insect growth chamber containing moistened cellucotton and the terminals were infested with five neonates of the appropriate insect species. The chamber was sealed with a clear plastic lid, and all chambers were randomized and placed in an incubator maintained at 27.7 C, 75 % RH, and a 16:8 (light:dark) photoperiod. Terminal buds were replaced and/or new terminals treated as above were added each Monday, Wednesday, and Friday. At 6 d after infestation, number of larvae that survived was recorded and the number was reduced to one insect/chamber. Data recorded included weight of larvae at 10 d, days to pupation, pupal weight, days to adult eclosion, and sex. All experiments were designed in a randomized complete block with 20 replications. Data were subjected to analyses of variance (SAS, 1989) and significantly different means were separated by Waller-Duncan k-ratio t-test.

After the initial bioassays, a fourth bioassay was conducted with several chlorothalonil-based products to determine whether activity noted with Bravo 720® was due to chlorothalonil or to formulation. This test was conducted with the fall armyworm only, and evaluated the following treatments: (a) an untreated control, (b) Bravo 720® at 3.13 mL/L H_2O (0.84 kg ai/ha), (c) Bravo 720® at 4.69 mL/L H_2O (1.13 kg ai/ha), (d) Bravo Ultrex® at 4.19 g/L H_2O (1.29 kg ai/ha), (e) Echo 720® at 4.69 mL/L H_2O (1.13 kg ai/ha), (f) Emblem 500® at 6.26 mL/L H_2O (1.13 kg ai/ha), and (g) Terranil 6L® at 4.69 mL/L H_2O (1.13 kg ai/ha). Procedures, experimental design, and data collection were as described above. Orthogonal comparisons were used to compare selected treatment effects (SAS, 1989).

Bioassays using insect diet were conducted to determine the LD_{50} for two chlorothalonil-based products, Bravo 720® and Bravo Ultrex®, on the corn earworm, fall armyworm and velvetbean caterpillar. These products were incorporated in the diet at 0, 50, 100, 200, 400, 800, 1600, and 3200 ppm of the commercial formulation. For bioassay, the diet was diluted 3:1 (diet:water) and blended for *ca.* 1 min. The diet was poured into 2500-mL beakers which were placed in a waterbath at 55 C to prevent solidification. Four hundred mL of the diet was dispensed into a blender and the appropriate quantity of fungicide was added. The diet was blended for 1 min before dispensing *ca.* 10 mL into each of 30 one-oz jelly cups. After the diet solidified and cooled, one neonate was placed on the diet surface and the diet cup was capped with a paper lid. All cups were randomized and then placed in an incubator maintained as above. Data were collected on larval weight at 10 d, percentage survival to pupation, days to pupation, pupal weight, days to adult eclosion, and percentage survival to the adult stage. Data were analyzed by polynomial regression analyses (SAS, 1989).

Results

Fungicides had their greatest effect on establishment and early development of corn earworm larvae (Table 1). All fungicides, with the exception of propiconazole, significantly reduced survival of neonate CEW on treated peanut terminal buds as compared with survival of neonates on untreated terminal buds. Chlorothalonil was most toxic to neonates, either alone or in combination with propiconazole or tebuconazole. Larvae that fed on terminal buds treated with all fungicides, except propiconazole and chlorothalonil + propiconazole, weighed significantly ($P \leq 0.05$) less at 10 d than larvae that fed on untreated peanut terminal buds. Interestingly, larvae which fed on propiconazole-treated terminal buds weighed significantly ($P \leq 0.05$) more at 10 d and pupated significantly ($P \leq 0.05$) sooner than larvae that fed on untreated foliage. Weight of pupae was significantly ($P \leq 0.05$) greater when larvae were fed foliage treated with chlorothalonil at the lower rate, chlorothalonil + tebuconazole, and chlorothalonil + propiconazole than when they were fed untreated or propiconazole-treated foliage. However, survival to pupation and the adult stage for larvae that initially established on fungicide-treated foliage was equivalent to that on the untreated foliage. Overall, chlorothalonil, alone or in combination with tebuconazole or propiconazole, was most detrimental to establishment and development of CEW larvae.

All fungicide treatments containing chlorothalonil,

Table 1. Survival and development of the corn earworm reared on peanut terminals treated with fungicides.

Treatment	Corn earworm[a] Larval survival at 6 d	Larval weight at 10 d	Survival to pupation	Days to pupation	Pupal weight	Days to adult eclosion	Survival to adult
	%	mg	%[b]	d	mg	d	%[b]
Untreated	76.0 a	75.5 b	75.0 a	22.4 a	277.3 b	32.0 a	70.0 a
Chlorothalonil[c] @ 3.13 mL/L	39.0 cd	27.5 c	55.0 a	22.5 a	355.9 a	30.6 a	40.0 a
Chlorothalonil[c] @ 4.69 mL/L	20.0 e	28.6 c	75.0 a	22.3 a	323.7 ab	31.7 a	55.0 a
Tebuconazole[d] @ 1.41 mL/L	59.0 b	38.7 c	65.0 a	21.8 a	317.6 ab	31.4 a	60.0 a
Chlorothalonil[c] @ 3.13 mL/L + Tebuconazole[d] @ 1.41 mL/L	52.0 bc	44.7 c	85.0 a	21.2 ab	357.7 a	30.6 a	70.0 a
Propiconazole[e] @ 0.78 mL/L	82.0 a	106.4 a	55.0 a	19.8 b	282.9 b	29.8 a	50.0 a
Chlorothalonil[c] @ 3.13 mL/L + Propiconazole[e] @ 0.78 mL/L	34.0 d	50.7 bc	80.0 a	20.7 ab	343.3 a	30.1 a	70.0 a

[a]Means in a column followed by the same letter are not significantly different ($P \leq 0.05$) using the Waller-Duncan K-ratio t-test.
[b]Survival after numbers were reduced to one larva/cup. Percentage data transformed to arcsine $\sqrt{\%}$ for analysis.
[c]Bravo 720®.
[d]Folicur 3.6 F®.
[e]Tilt 3.6 EC®.

alone or in combination with tebuconazole or propiconazole, significantly ($P \leq 0.05$) reduced establishment of FAW neonates on peanut terminal buds in comparison with establishment of neonates on untreated foliage (Table 2). Similarly, weight of FAW larvae at 10 d was significantly ($P \leq 0.05$) reduced when larvae were fed terminal buds treated with chlorothalonil, alone or in combination with propiconazole, compared with weight of larvae which were fed untreated foliage. As with the CEW, FAW larvae fed foliage treated with propiconazole weighed significantly ($P \leq 0.05$) more at 10 d than larvae fed untreated foliage. Survival to pupation and the adult stage was significantly ($P \leq 0.05$) reduced when larvae were fed tebuconazole compared to larvae fed untreated foliage, but survival was not reduced when larvae were fed a combination of chlorothalonil + tebuconazole. Time to pupation and adult emergence was greatest for larvae fed foliage treated with fungicides as compared with that required for larvae fed untreated foliage, with the exception of larvae fed propiconazole-treated foliage. Chlorothalonil, especially at the higher rate, had the greatest effect on larvae by extending the time in the larval stadia and delaying pupation and adult emergence. However, none of the fungicide treatments adversely affected pupal weight for fall armyworm. In fact, weight of pupae was significantly ($P \leq 0.05$) greater when larvae

Table 2. Survival and development of the fall armyworm reared on peanut terminals treated with fungicides.

Treatment	Fall armyworm[a] Larval survival at 6 d	Larval weight at 10 d	Survival to pupation	Days to pupation	Pupal weight	Days to adult eclosion	Survival to adult
	%	mg	%[b]	d	mg	d	%[b]
Untreated	72.0 a	122.9 bc	90.0 a	15.1 d	166.9 bc	22.9 c	80.0 a
Chlorothalonil[c] @ 3.13 mL/L	39.0 c	64.1 d	80.0 ab	18.5 b	174.4 abc	25.9 b	70.0 ab
Chlorothalonil[c] @ 4.69 mL/L	38.0 c	51.9 d	90.0 a	21.6 a	159.1 cb	29.4 a	80.0 a
Tebuconazole[d] @ 1.41 mL/L	75.0 a	143.5 ab	60.0 b	17.0 c	192.5 a	25.6 b	45.0 b
Chlorothalonil[c] @ 3.13 mL/L + Tebuconazole[d] @ 1.41 mL/L	47.0 bc	107.0 c	95.0 a	18.0 bc	190.7 a	25.9 b	95.0 a
Propiconazole[e] @ 0.78 mL/L	85.0 a	168.8 a	90.0 a	15.6 d	185.5 ab	22.9 c	80.0 a
Chlorothalonil[c] @ 3.13 mL/L + Propiconazole[e] @ 0.78 mL/L	53.0 b	77.8 d	80.0 ab	17.8 bc	167.8 bc	25.5 b	75.0 a

[a]Means in a column followed by the same letter are not significantly different ($P \leq 0.05$) using the Waller-Duncan K-ratio t-test.
[b]Survival after numbers were reduced to one larva/cup. Percentage data transformed to arcsine $\sqrt{\%}$ for analysis.
[c]Bravo 720®.
[d]Folicur 3.6 F®.
[e]Tilt 3.6 EC®.

were fed foliage treated with tebuconazole or chlorothalonil + tebuconazole than when they were fed untreated foliage. As with CEW, chlorothalonil reduced establishment and slowed early development of FAW larvae. Tebuconazole reduced survival to pupation, increased time to pupation, increased weight of pupae, and decreased survival of FAW to the adult stage.

Initial establishment and survival of VBC larvae on peanut terminal buds were significantly ($P \leq 0.05$) reduced by all fungicides (Table 3). With the exception of larvae fed propiconazole, weight of larvae at 10 d that established on peanut terminal buds was significantly ($P \leq 0.05$) lower and rates of development were significantly ($P \leq 0.05$) slower for larvae fed fungicide-treated foliage compared with larvae fed untreated foliage. As with the previous two insects, velvetbean caterpillar larvae fed terminal buds treated with propiconazole actually weighed significantly ($P \leq 0.05$) more at 10 d than larvae fed untreated foliage. Tebuconazole and chlorothalonil, alone and in combination with tebuconazole, increased time to pupation and to adult emergence, but the time to pupation and adult emergence of larvae fed propiconazole was equivalent to that for larvae fed untreated foliage. Chlorothalonil at the high rate and in combination with tebuconazole significantly ($P \leq 0.05$) reduced survival to adult emergence compared with the untreated control. As with the previous two species, chlorothalonil, especially at the higher rate, adversely affected survival and development of VBC larvae fed treated peanut terminal buds.

Several chlorothalonil-based fungicides were evaluated for activity against the fall armyworm to determine if the activity noted in previous tests was the result of chlorothalonil or to other factors associated with formulation of chlorothalonil. Orthogonal comparisons showed that larvae fed terminal buds treated with all chlorothalonil-based fungicides had significantly ($P \leq 0.001$) reduced FAW survival at 6 d, significantly ($P \leq 0.001$) reduced larval weight at 10 d, significantly ($P \leq 0.001$) increased days to pupation, significantly ($P \leq 0.01$) reduced pupal weight, and significantly ($P \leq 0.001$) increased days to adult eclosion when compared to larvae fed untreated foliage (Table 4). Several significant differences were noted also among the products evaluated. Most notably, Bravo Ultrex® significantly ($P \leq 0.001$) increased the days to pupation and adult emergence, significantly ($P \leq 0.001$) reduced pupal weight, and significantly ($P \leq 0.001$) reduced survival to the adult stage when compared with larvae fed foliage treated with the high rate of Bravo 720® (Table 4). Little or no differences were noted in most developmental parameters for FAW larvae fed terminals treated with the other chlorothalonil-based fungicides (Table 4).

Figures 1-3 show the effects on the corn earworm, fall armyworm, and velvetbean caterpillar, respectively, of Bravo 720® and Bravo Ultrex® on establishment, weight of larvae at 10 d, survival to pupation, and days to pupation. Data for survival at 6 d or to pupation were inappropriate for probit analyses to determine LD_{50s}; survival remained high from 0 to 200-400 ppm and then dropped precipitously at 400-800 ppm of Bravo 720® and Bravo Ultrex®. Multiple regression analyses showed that the fifth-degree polynomial best described survival of corn earworm and fall armyworm larvae at 6 d for both Bravo 720® and Bravo Ultrex®, survival of corn earworm and fall armyworm to pupation for both Bravo 720® and Bravo Ultrex®, weight of corn earworm and fall armyworm larvae at 10 d on both Bravo 720® and Bravo Ultrex® (Figs. 1-3). The linear, quadratic, and cubic components best described days to pupation for the corn earworm on both Bravo 720® and Bravo Ultrex® (Fig. 1D), and survival to pupation for velvetbean caterpillar larvae fed either Bravo 720® or Bravo Ultrex® (Fig. 3C). Both the linear and quadratic components were signifi-

Table 3. Survival and development of the velvetbean caterpillar reared on peanut terminals treated with fungicides.

	Velvetbean caterpillar[a]						
Treatment	Larval survival at 6 d	Larval weight at 10 d	Survival to pupation	Days to pupation	Pupal weight	Days to adult eclosion	Survival to adult
	%	mg	%[b]	d	mg	d	%[b]
Untreated	90.0 a	183.6 b	100.0 a	15.2 e	259.1 a	23.7 d	95.0 ab
Chlorothalonil[c] @ 3.13 mL/L	60.0 c	53.7 d	95.0 a	19.5 c	219.1 b	28.1 c	90.0 ab
Chlorothalonil[c] @ 4.69 mL/L	42.0 d	16.1 e	65.0 b	25.1 a	181.7 c	34.3 a	60.0 c
Tebuconazole[d] @ 1.41 mL/L	77.0 b	110.3 c	100.0 a	16.9 d	262.7 a	25.1 d	100.0 a
Chlorothalonil[c] @ 3.13 mL/L + Tebuconazole[d] @ 1.41 mL/L	61.0 c	38.0 de	80.0 ab	20.5 bc	246.9 a	29.4 bc	60.0 c
Propiconazole[e] @ 0.78 mL/L	65.0 bc	229.9 a	90.0 a	14.6 e	259.4 a	23.2 d	80.0 abc
Chlorothalonil[c] @ 3.13 mL/L + Propiconazole[e] @ 0.78 mL/L	47.0 d	28.5 e	90.0 a	21.6 b	213.8 b	30.1 b	70.0 bc

[a]Means in a column followed by the same letter are not significantly different ($P \leq 0.05$) using the Waller-Duncan K-ratio t-test.
[b]Survival after numbers were reduced to one larva/cup. Percentage data transformed to arcsine $\sqrt{\%}$ for analysis.
[c]Bravo 720®.
[d]Folicur 3.6 F®.
[e]Tilt 3.6 EC®.

Table 4. Orthogonal comparisons of the effects for chlorothalonil-based fungicides on survival and development of the fall armyworm reared on peanut terminals treated with fungicides.

	Fall armyworm[a]						
Orthogonal comparison	Larval survival at 6 d	Larval weight at 10 d	Survival to pupation	Days to pupation	Pupal weight	Days to adult eclosion	Survival to adult
	%	mg	%[b]	d	mg	d	%[b]
Untreated vs. all fungicide treatments	82.0 vs. 27.3***	90.3 vs. 28.5***	75.0 vs. 73.3 ns	17.3 vs. 22.5***	200.2 vs. 183.2**	25.1 vs. 30.0***	75.0 vs. 69.2 ns
Bravo 720® @ 3.13 mL/L vs. Bravo 720® @ 4.69 mL/L	28.0 vs. 26.0 ns	35.0 vs. 30.5 ns	70.0 vs. 90.0 ns	21.0 vs. 21.2 ns	208.7 vs. 185.0**	29.6 vs. 29.3 ns	70.0 vs. 80.0 ns
Bravo 720® @ 4.69 mL/L vs. Bravo Ultrex® @ 4.19 g/L	26.0 vs. 21.0 ns	30.5 vs. 24.4 ns	90.0 vs. 30.0***	21.2 vs. 29.7***	185.0 vs. 105.0***	29.3 vs. 38.5***	80.0vs.30.0***
Bravo 720® @ 4.69 mL/L vs. Echo 720® @ 4.69 mL/L	26.0 vs. 24.0 ns	30.5 vs. 31.0 ns	90.0 vs. 85.0 ns	21.2 vs. 21.0 ns	185.0 vs. 183.9 ns	29.3 vs. 29.1 ns	80.0 vs. 80.0 ns
Bravo 720® @ 4.69 mL/L vs. Emblem 500® @ 4.69 mL/L	26.0 vs. 42.0**	30.5 vs. 26.0 ns	90.0 vs. 65.0 ns	21.2 vs. 20.0 ns	185.0 vs. 192.6 ns	29.3 vs. 28.2 ns	80.0 vs. 60.0 ns
Bravo 720® @ 4.69 mL/L vs. Terranil 6L® @ 4.69 mL/L	26.0 vs. 23.0 ns	30.5 vs. 23.8 ns	90.0 vs. 100.0 ns	21.2 vs. 22.1 ns	185.0 vs. 180.6 ns	29.3 vs. 30.3 ns	80.0 vs. 95.0**

[a]ns = nonsignificant; ** = significant at the $P \le 0.01$ level of confidence; *** = significant at the $P \le 0.001$ level of confidence.
[b]Survival after numbers were reduced to one larva/cup. Percentage data transformed to arcsine $\sqrt{\%}$ for analysis.

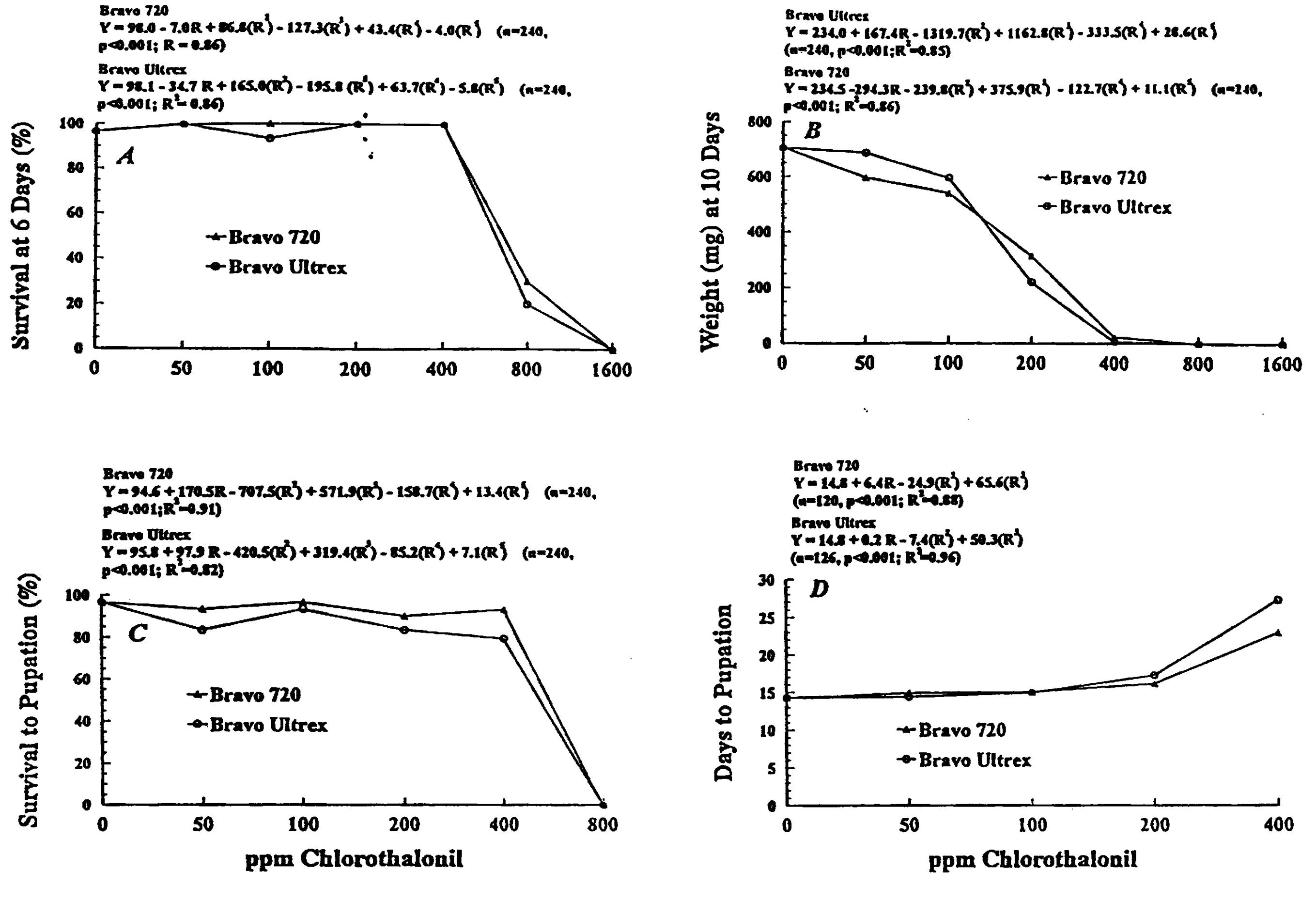

Fig. 1. Effect of Bravo 720® and Bravo Ultrex® on corn earworm: *A*. Survival at 6 d; *B*. Weight at 10 d; *C*. Survival to pupation; and *D*. Days to pupation (data scaled by a factor of 500 for analysis and presentation).

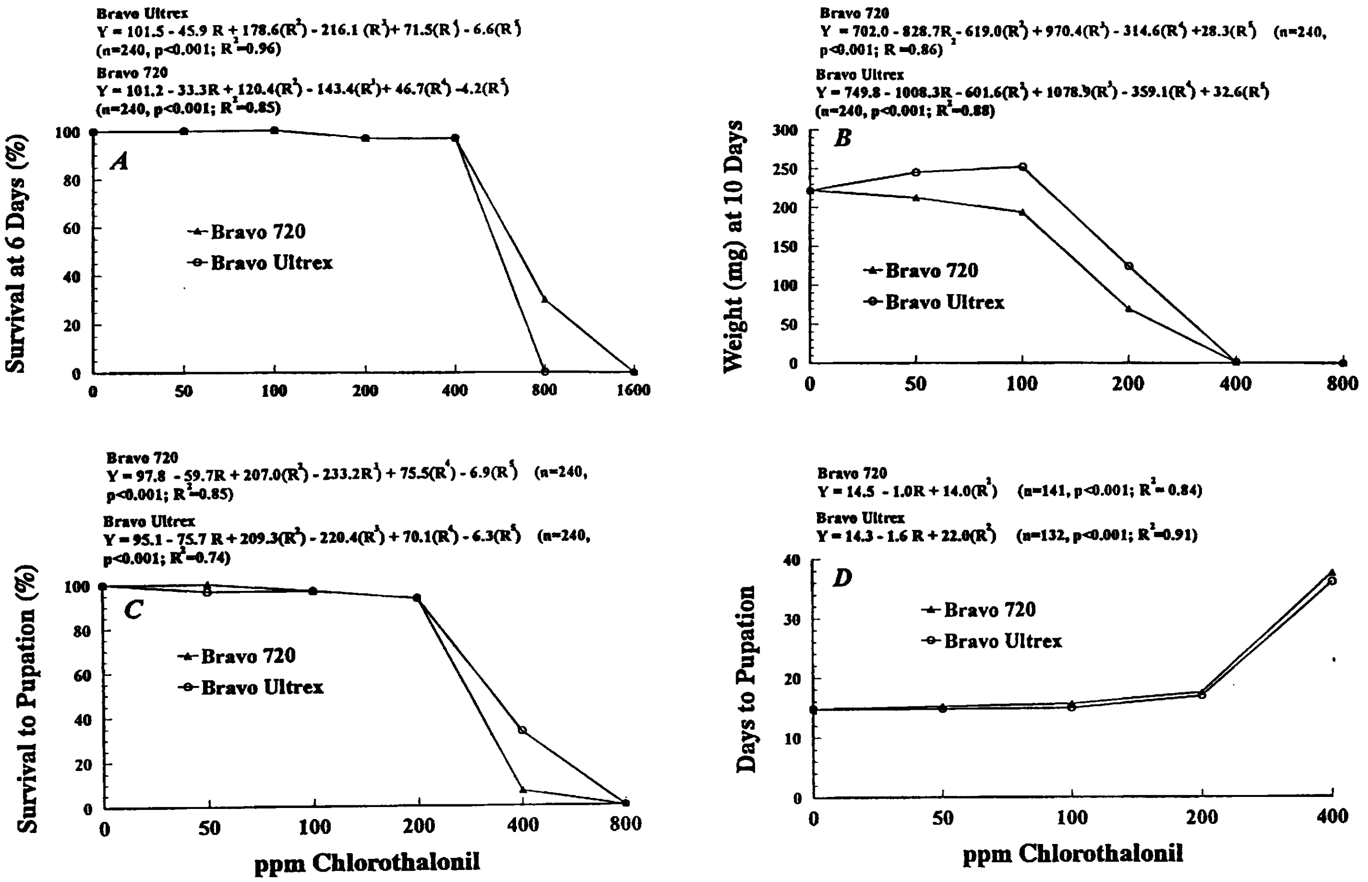

Fig. 2. Effect of Bravo 720® and Bravo Ultrex® on fall armyworm: *A*. Survival at 6 d; *B*. Weight at 10 d; *C*. Survival to pupation; and *D*. Days to pupation (data scaled by a factor of 500 for analysis and presentation).

cant ($P \leq 0.01$) for days to pupation for the fall armyworm on both Bravo 720® and Bravo Ultrex® (Fig. 2D) and for velvetbean caterpillar larvae fed on Bravo Ultrex® (Fig. 3D). Only the linear component of regression was significant ($P \leq 0.01$) for weight of larvae at 10 d on both Bravo 720® and Bravo Ultrex® and days to pupation for the velvetbean caterpillar fed diet treated with Bravo 720® (Fig. 3B,D). T-tests were not significant when comparing the regressions for Bravo 720® versus Bravo Ultrex® within an insect for any of the variables measured. Thus, the action of Bravo 720® and Bravo Ultrex® were not significantly ($P \leq 0.01$) different on the CEW, FAW, or VBC.

Discussion

Fungal diseases of peanut—e.g., early and late leaf spot, white mold, rhizoctonia limb rot—are limiting factors in the profitable production of peanut in the southern U.S. Chlorothalonil is routinely applied on a 10-14 d schedule throughout the growing season to control leaf spot diseases of peanut. A new group of fungicides, the sterol demethylation-inhibiting fungicides, are highly effective against both foliar and soil-borne pathogens of peanut and have recently been registered for use on peanut (Brenneman and Culbreath, 1994; Brenneman *et al.*, 1994). Application of these fungicides to peanut foliage often occurs during periods when lepidopterous insects are ovipositing and/or larvae are feeding on peanut foliage. As larvae emerge from eggs and migrate to preferred feeding sites on the peanut plant and as they consume foliage that has been treated, they are exposed to the fungicides. These fungicides affect establishment and survival of lepidopterous larvae as they feed on treated foliage.

Of the fungicides evaluated, chlorothalonil most adversely affected early establishment, survival, and development of the major defoliating insects that attack peanut. Chlorothalonil reduced establishment and early survival of corn earworm, fall armyworm, and velvetbean caterpillar larvae on peanut terminals. It also reduced the weight of corn earworm, fall armyworm, and velvetbean caterpillar larvae at 10 d and increased the time to pupation for fall armyworm and velvetbean caterpillar larvae. Similarly, tebuconazole adversely affected early survival and establishment, decreased 10-d weight and extended time to pupation for corn earworm and velvetbean caterpillar larvae, but had no effect on early survival of fall armyworm larvae. Propiconazole, on the other hand, did not affect establishment and early survival of corn earworm and fall armyworm larvae on

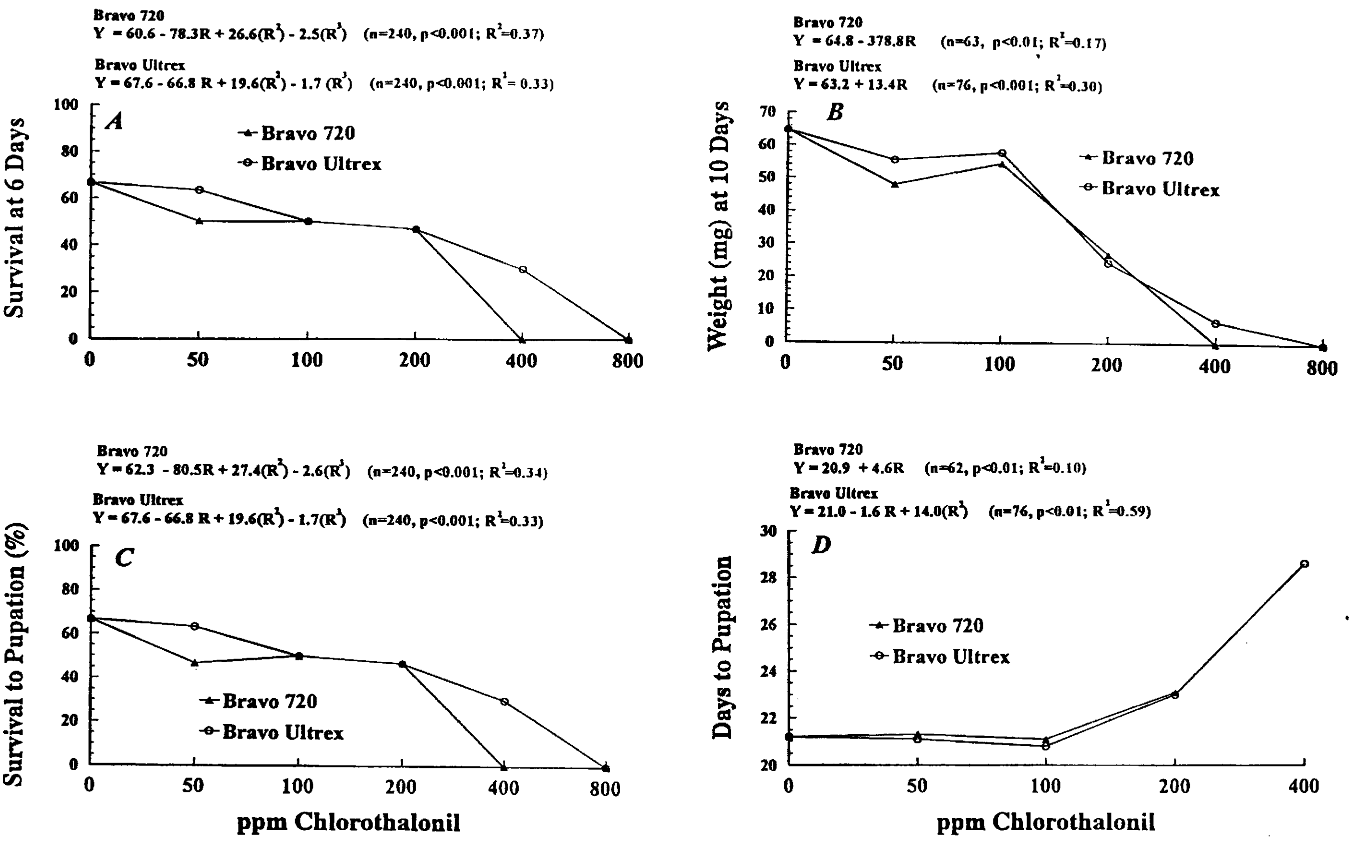

Fig. 3. Effect of Bravo 720® and Bravo Ultrex® on velvetbean caterpillar: *A*. Survival at 6 d; *B*. Weight at 10 d; *C*. Survival to pupation; and *D*. Days to pupation (data scaled by a factor of 500 for analysis and presentation).

peanut foliage and actually increased the 10-d weight of larvae for all three insect species. Thus, while chlorothalonil and tebuconazole negatively impacted survival and development of lepidopterous larvae, propiconazole actually enhanced early development of these insects.

Evaluation of five chlorothalonil-based fungicides showed that all adversely affected early survival and development of fall armyworm larvae. Thus, activity previously noted for Bravo 720® was a direct response to chlorothalonil and was not related to formulation. However, Bravo Ultrex®, a new, dry, water-soluble formulation of Bravo®, actually had a greater impact on survival and development of the fall armyworm than did Bravo 720®. However, evaluation of different concentrations of Bravo 720® and Bravo Ultrex® in the meridic diet of the corn earworm, fall armyworm, and velvetbean caterpillar showed no measurable difference between Bravo Ultrex® and Bravo 720® on the developmental parameters of these insects. Both fungicides were most detrimental to all three insects at concentrations of 400 to 800 ppm which is equivalent to 1.6 to 3.2 mL of fungicide to 1 L of diet. Recommendation rates of application for chlorothalonil are 3.13 to 4.69 mL/L H_2O (= 1-1.5 pt/40 gal H_2O). Thus, the application rates in the field are well above the levels that adversely affected survival and development in laboratory studies.

Lepidopterous insects such as the corn earworm, fall armyworm, and velvetbean caterpillar lay their eggs on peanut leaflets, generally on the underside of a leaflet, and early instars feed on or within the folded leaves of developing terminals (Pencoe and Lynch, 1982; Deitz *et al.*, 1992). As neonates emerge and migrate to feeding sites, they are exposed to fungicide that has been sprayed onto the peanut foliage. Likewise, as they consume foliage, they consume fungicide that has been sprayed onto the plant. Extrapolating these laboratory data to the field, one would expect chlorothalonil and tebuconazole to adversely affect early survival and establishment of neonates of the CEW, FAW, and VBC as they migrate to feeding sites and feed on fungicide-treated peanut terminals. Conversely, propiconazole would not affect larval survival and establishment. In fact, larvae feeding on propiconazole would gain weight and develop faster than if they were feeding on untreated foliage.

Survival and development of lepidopterous larvae on peanut are influenced by a myriad of interacting factors such as parasites and predators, sunlight, precipitation, etc. These data indicate that fungicides applied to peanut may be detrimental to the survival and development of defoliating insects, or may stimulate development of larvae as they feed on fungicide-treated foliage. Fungicides also may affect survival of predators and parasites which prey on defoliating insects. Likewise, sunlight and precipitation degrade fungicides and affect concentration of active ingredient over time. Thus, an understanding of the impact of fungicides on lepidopterous pests of peanut would require a study of their effects on parasites and predators, similar to that reported by de Rivero and Poe (1981), a more in-depth study on the concentration of fungicide on these parasites and predators, and more knowledge on the degradation of the fungicides by sunlight and precipitation.

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