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Tropical Agricultural Research Vol. 9 1997, 358-367

Impact of Post–treatment Temperatures on the Toxicity of Mixtures Comprising of Deltamethrin and Different Vegetable Oils against the Susceptible Strain of *Tribolium castaneum* (Herbst)

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ABSTRACT. *The effect of post–treatment temperature on the toxicity of deltamethrin and its mixed formulations with various vegetable oils viz., sesame oil, karanj oil, neem oil, citronella oil along with standard synergist piperonyl butoxide in four ratios, i.e., 1:1, 1:2, 1:4 and 1:8 applied by direct spray method was assessed at 10^0, 23^0 and 30^0C, against the susceptible strain (S–strain) of red flour beetle, Tribolium castaneum (Herbst). The LC_{50} values and temperature coefficients were calculated. Deltamethrin and its mixtures with sesame oil (1:1, 1:2) and neem oil (1:2, 1:4, 1:8) showed a negative temperature coefficient, being more toxic at 10^0 and/or 23^0C than at 30^0C, while the mixtures with karanj oil (1:1, 1:4, 1:8), citronella oil (1:4, 1:8) and piperonyl butoxide (1:4, 1:8) exhibited a positive temperature coefficient, being more toxic at 23^0 and/or 30^0C than at 10^0C. However, the mixtures of deltamethrin with sesame oil (1:8) and piperonyl butoxide (1:2) exhibited neutral temperature correlation. The results suggest that the type of vegetable oil used with the toxicant, affects the temperature coefficient to be positive, negative or neutral.*

INTRODUCTION

Temperature, in particular the post–treatment temperature, is one of the numerous factors which influences the insecticide toxicity. A negative correlation between temperature and toxicity has been observed for DDT, pyrethrins (Pradhan, 1949; Guthrie, 1950; Blum and Kearns, 1956) and pyrethroids (Narahashi, 1971; Hadaway, 1978; Henrick *et al.*, 1980). However, according to Sparks *et al.* (1982 and 1983) and Song–Hao (1986) temperature/toxicity relationship of pyrethroids may vary depending on the insect species and compound.

The influence of post-treatment temperature on the toxicity of insecticides to stored–grain pest *Tribolium castaneum* (Herbst) has been reported by many researchers (Pradhan, 1949; Tyler and Binns, 1982; Watters *et al.*, 1983). However there is no information on the effect of post–treatment temperature on the combined action of insecticide and vegetable oils. During the last nine years, *T. castaneum* showed a 71.7–fold increase in resistance to deltamethrin. Therefore, the use of mixed formulations is considered to be more satisfactory in controlling pests with less contamination of food grains (Sridevi, 1996). Hence, the effect of post–treatment temperatures on the toxicity of mixtures formulated separately in four ratios with deltamethrin and non–toxic vegetable oils against the adults of *T. castaneum* (S–strain) was investigated.

MATERIALS AND METHODS

Deltamethrin was formulated alone and in combination with each of the four non–toxic vegetable oils, *i.e.*, sesame (*Sesamum indicum*) oil, karanj (*Pongamia glabra*) oil, neem (*Azadirachta indica*) oil, citronella oil along with synergist piperonyl butoxide at ratios of 1:1, 1:2, 1:4 and 1:8. The insecticide and the non–toxic vegetable oils were formulated as emulsions. Technical grade deltamethrin (98.5%) was used. The vegetable oils (sesame, karanj, neem and citronella) were procured from the Division of Agricultural Chemicals, Indian Agricultural Research Institute, New Delhi. Piperonyl butoxide was supplied by M/s. Bombay Chemicals, Bombay.

Xylene was used as a solvent in the preparation of stock solutions (20%) of the insecticide and vegetable oils. These were diluted with the required quantity of distilled water containing emulsifier (0.500 g Triton X–100/100 ml of distilled water) to obtain 1% emulsion. This emulsion was further diluted with blank emulsion (5 ml xylene + 0.500 g Triton X–100, made to 100 ml of distilled water) for the preparation of final concentrations. This procedure enabled to maintain the solvent and emulsifier levels at 5 and 0.5%, respectively, in the final concentrations. For formulating the mixture of insecticide and the non–toxic vegetable oil, the two stock solutions having equal concentration of insecticide and a non–toxic vegetable oil was mixed depending upon the ratios, *viz.*, 1:1, 1:2, 1:4 and 1:8. Further dilutions of the mixture of aforesaid stock solution of a particular proportion was done in the same way, as in the case of the formulation of an insecticide alone, to obtain the final emulsion concentrations. The toxicity (LC_{50}) of each combination was evaluated against the adults of *T. castaneum* (S–strain).

For pre–conditioning, *T. castaneum* adults (S–strain, 20 +/- 2 day old) were kept at 27 +/- 10°C without food in covered glass jars for 1 h before treatment. The treatment involved the direct spraying of the insects under Potter's tower. Ten adults were placed in each petri dish (10 cm diameter) and sprayed with one ml of each concentration at a pressure of 340 g cm^{-2}. In case of control, petri dishes were sprayed with blank emulsions containing no toxicant or the non–toxic chemical. There were three replications for each concentration and untreated control. The sprayed petri dishes were dried for about five minutes before transferring into incubators maintained at 10, 23 and 30°C temperature. Mortality counts were taken 48 h after the treatment. The percent mortality in control, if any, was corrected in the treatments using Abbott's formula (1925). The moribund insects were also counted as dead. The average percent mortality in each concentration was calculated and the corresponding probit of each percent kill was obtained from Finney (1971). The LC_{50} value for deltamethrin and its combination with each vegetable oil was calculated using LC_{50} programme (Indostat Services, Hyderabad).

On the basis of LC_{50} values of each combination of deltamethrin and vegetable oils in four ratios (1:1, 1:2, 1:4 and 1:8) the temperature coefficients along with 't' values were calculated to find out whether the differences in toxicity at two different temperatures, *i.e.*, 10 and 23°C, 23 and 30°C and 10 and 30°C temperature, are significant. The temperature coefficient for each combination was calculated by dividing the larger LC_{50} value by smaller LC_{50} value. Temperature coefficient will be negative (–) if the LC_{50} value at higher temperature was significantly greater than at lower temperature, whereas a positive (+) temperature coefficient will be observed if the converse was true. If the LC_{50} values between the two temperatures were not significantly different, temperature coefficient will be neutral.

RESULTS AND DISCUSSION

Variation in the toxicity at 10° and 23°C

When LC_{50} values 10° and 23°C are compared, deltamethrin with sesame oil (1:4); karanj oil (1:1, 1:2, 1:4); neem oil (1:1, 1:2, 1:4, 1:8); citronella oil (1:8) and piperonyl butoxide (1:1, 1:4, 1:8) exhibited significant positive temperature coefficients indicating that their toxicity was more at 23°C than at 10°C against *T. castaneum* (Table 1). However, deltamethrin alone and its combinations with sesame oil (1:1, 1:2, 1:8); karanj oil (1:8);

citronella oil (1:1, 1:2, 1:4) and piperonyl butoxide (1:2) were not significantly different at these temperatures.

Table 1. Effect of post–treatment temperatures on the toxicity of deltamethrin and its combinations with various vegetable oils to the adults of *T. castaneum* (S–strain) by direct spray method.

Insecticide/Insecticide+ vegetable oil		LC$_{50}$ values (%) at			Temperature coefficient[a] between		
		10°C	23°C	30°C	10°C-23°C	23°C-30°C	10°C-30°C
Deltamethrin		0.00079	0.00077	0.00136	1.02^{NS}0	1.77**-	1.72**-
Deltamethrin + Sesame Oil	1:1	0.00136	0.00173	0.00280	1.27^{NS}0	1.62*-	2.05**-
	1:2	0.00267	0.00244	0.00744	1.09^{NS}0	3.05**-	2.79**-
	1:4	0.00918	0.00467	0.00697	1.96**+	1.49^{NS}0	1.32^{NS}0
	1:8	0.01281	0.01044	0.02226	1.23^{NS}0	2.13^{NS}0	1.74^{NS}0
Deltamethrin + Karanji oil	1:1	0.00488	0.00293	0.00283	1.66**+	1.03^{NS}0	1.72*+
	1:2	0.00603	0.00339	0.00451	1.78*+	1.33^{NS}0	1.34^{NS}0
	1:4	0.04161	0.00871	0.00333	4.78**+	2.61**+	12.49**+
	1:8	0.02567	0.03133	0.01532	1.22^{NS}0	2.04*+	1.67*+
Deltamethrin + Neem oil	1:1	0.00270	0.00148	0.00214	1.82**+	1.44^{NS}0	1.02^{NS}0
	1:2	0.00611	0.00381	0.00727	1.60*+	1.91*-	1.19^{NS}0
	1:4	0.00970	0.00526	0.03605	1.84*+	6.85**-	3.72*-
	1:8	0.02012	0.00812	0.03529	2.48**+	4.35**-	1.75^{NS}0
Deltamethrin + Citronella oil	1:1	0.00279	0.00358	0.00196	1.28^{NS}0	1.82**+	1.42^{NS}0
	1:2	0.00379	0.00403	0.00164	1.06^{NS}0	2.46**+	2.31^{NS}0
	1:4	0.00660	0.00552	0.00388	1.19^{NS}0	1.42^{NS}0	1.70*+
	1:8	0.01467	0.00951	0.01520	1.54*+	1.60*-	1.04^{NS}0
Deltamethrin + PBO	1:1	0.00175	0.00081	0.00197	2.16*+	2.43**-	1.12^{NS}0
	1:2	0.00377	0.00220	0.00199	1.71^{NS}0	1.10^{NS}0	1.89^{NS}0
	1:4	0.00614	0.00239	0.00078	2.57*+	3.06**+	7.87**+
	1:8	0.00776	0.00268	0.00042	2.89*+	6.38**+	18.48**+

A temperature coefficient for each formulation = Larger LC$_{50}$ Value ÷ Smaller LC$_{50}$ Value; negative (-), positive (+) or neutral (0)
* Significant at 5 % level; ** Significant at 1 % level; NS- Not Significant

Variation in toxicity at 23° and 30°C

When the LC_{50} values were compared at 23° and 30°C, a significant negative temperature coefficient was observed for deltamethrin alone. Also, the mixtures of deltamethrin with sesame oil (1:1, 1:2), neem oil (1:2, 1:4, 1:8), citronella oil (1:8) and piperonyl butoxide (1:1) gave negative temperature coefficients indicating that they are more effective against *T. castaneum* at 23° than at 30°C. In contrast, the combinations of deltamethrin with karanj oil (1:4, 1:8), citronella oil (1:1, 1:2) and piperonyl butoxide (1:4, 1:8) demonstrated significant positive temperature coefficient. The remaining seven combinations showed a neutral temperature coefficient (Table 1).

Variation in toxicity at 10° and 30°C

When LC_{50} values 10° and 30°C were compared, the toxicity of deltamethrin alone and its mixtures with sesame oil (1:1, 1:2) and neem oil (1:4) indicated significant negative temperature coefficients (Table 1). On the other hand, significant positive temperature coefficients were observed in mixed formulation of deltamethrin with karanj oil (1:1, 1:4, 1:8), citronella oil (1:4) and piperonyl butoxide (1:4, 1:8), while the rest of the mixtures were not significantly different at these temperatures.

Several workers (Pradhan, 1949; Guthrie, 1950; Vinson and Kearns, 1952) reported that the toxicity of DDT and pyrethrins increases with a decrease in temperature. Pyrethroids also show a similar effect in relation to temperature (Sparks *et al.*, 1982 and 1983).

Toxicity of pyrethroids was lower at 20°C than at 30°C against *T. castaneum* (Desmarchelier, 1977). Watters *et al.* (1983) reported that effectiveness of fenvalerate and cypermethrin against *T. castaneum* adults was more at 20° than at 10° and 30°C. On the basis of findings presented in Table 1 and Figure 1, deltamethrin and its mixtures with each of the two vegetable oils, *viz.*, sesame oil (1:1, 1:2) and neem oil (1:2, 1:4, 1:8) were found to be more toxic at 10° and/or 23°C compared to 30°C. Negative temperature coefficient of pyrethroids have also been reported in *T. confusum* (Alexandrescu, 1986) and pulse beetles (Rahman and Yadav, 1987). One likely reason for the greater toxic effect of pyrethroids at lower temperatures may be related to the greater sensitivity of insect nervous system to pyrethroid poisoning at low temperatures (Gammon 1978, 1980). The combination containing deltamethrin and sesame oil (1:8) showed neutral temperature

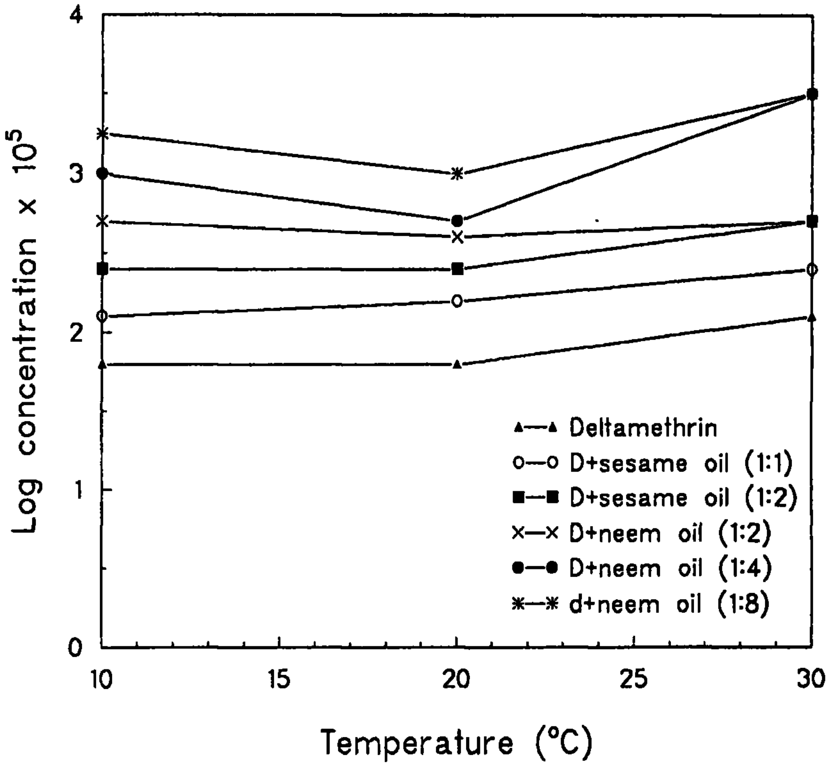

Figure 1. Deltamethrin, Deltamethrin + Sesame oil (1:1, 1:2), Deltamethrin + Neem oil (1:2, 1:4, 1:8) showing negative temperature correlation.

coefficients (Figure 3), whereas, inconsistent results were obtained in the mixtures of deltamethrin with sesame oil (1:4) and neem oil (1:1) (Figure 4). Remaining three non–toxic vegetable oils, *viz.*, karanj oil (1:1, 1:4, 1:8), citronella oil (1:4, 1:8) and piperonyl butoxide (1:4, 1:8), when used in combination with deltamethrin, exhibited a greater toxicity at 23° and/or 30°C than at 10°C (Figure 2), whereas, the mixture containing deltamethrin and piperonyl butoxide (1:2) exhibited neutral temperature coefficient (Figure 3), while the rest of the combinations (Deltamethrin + karanj oil, 1:2; Deltamethrin + citronella oil, 1:1, 1:2; Deltamethrin + PBO, 1:1) showed inconsistent results (Figure 4).

The evidence for a negative temperature effect is consistent with DDT and its analogs and naturally occurring pyrethrins (with rare exceptions). A positive temperature effect occurs with organophosphates and carbamates (Harris and

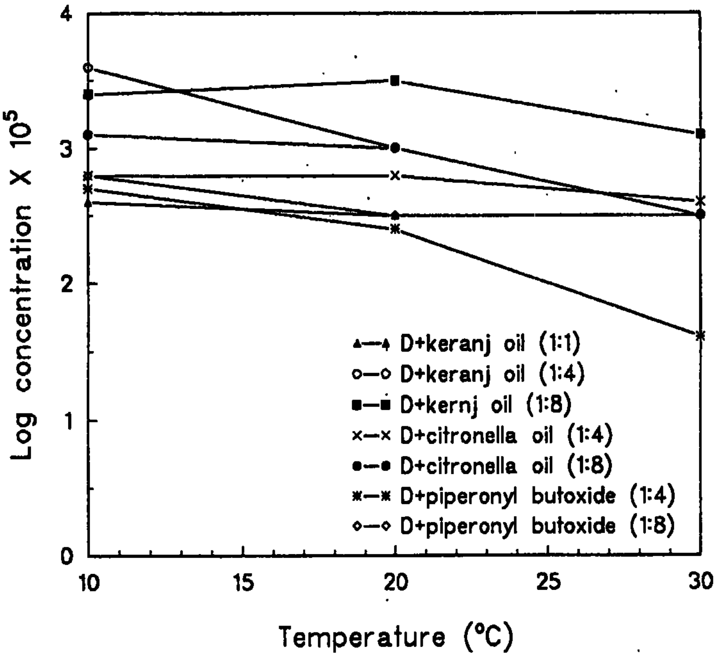

Figure 2. **Deltamethrin + Karanj oil (1:1, 1:4, 1:8), Deltamethrin + Citronella oil (1:4, 1:8), Deltamethrin + PBO (1:4, 1:8) showing positive temperature correlation.**

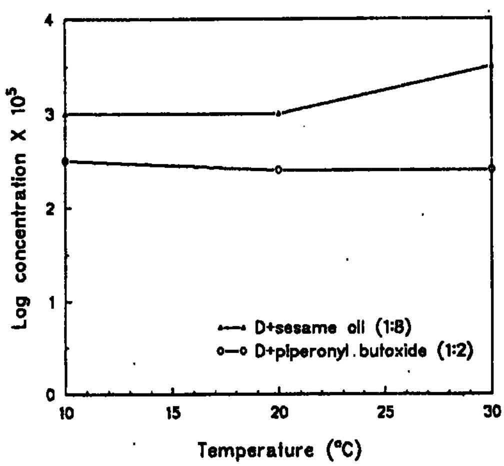

Figure 3. **Deltamethrin + Sesame oil (1:8) and Deltamethrin + PBO (1:2) showing neutral temperature correlation.**

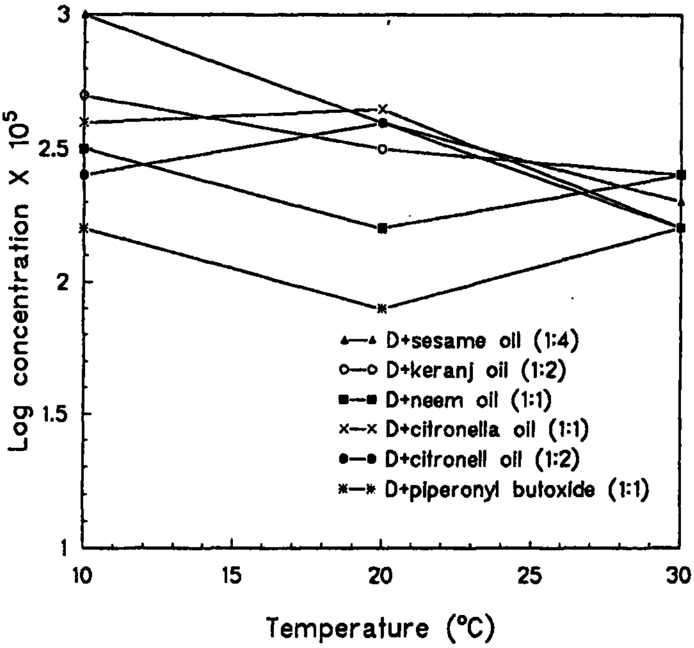

Figure 4. **Deltamethrin + Sesame oil (1:4), Deltamethrin + Karanj oil (1:2) and Deltamethrin + Neem oil (1:1), Deltamethrin + Citronella oil (1:1, 1:2) and Deltamethrin + PBO (1:1) showing inconsistent results.**

Kinoshita, 1977; Tyler and Binns, 1982). However, the pyrethroids have examples in both categories (Song–Hao, 1986). The present results also demonstrate that even though deltamethrin and its mixtures with sesame oil (1:1, 1:2) and neem oil (1:2, 1:4, 1:8) showed negative temperature coefficients, the mixtures with karanj oil (1:1, 1:4, 1:8) citronella oil (1:4, 1:8) and piperonyl butoxide (1:4, 1:8) exhibited positive temperature coefficients, suggesting that the type of vegetable oils used with the toxicant, affects the toxicity and the effectiveness of the mixed formulations against *T. castaneum*.

CONCLUSIONS

Sesame oil (1:1, 1:2) and neem oil (1:2, 1:4, 1:8) in combination with deltamethrin were more toxic at 10° and/or 23°C as compared to 30°C indicating a negative temperature correlation for *T. castaneum* (S–strain), whereas karanj oil (1:1, 1:4, 1:8), citronella oil (1:4, 1:8) and piperonyl butoxide (1:4, 1:8) were associated with positive temperature coefficients, *i.e.*, being more toxic at 23° and/or 30°C than at 10°C. The mixtures of deltamethrin with sesame oil (1:8) and piperonyl butoxide (1:2) exhibited neutral temperature correlation. The results obtained in these studies demonstrated that various vegetable oils in combination with deltamethrin should be regarded as temperature specific and some consideration should be given to their effectiveness at different temperatures.

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