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Mode of Action of Antifeeding Compounds in Larvae of the Tobacco Cutworm, *Spodoptera litura* (F.) (Lepidoptera: Noctuidae) IV. Effect of Topical Application with Chlordimeform and Clerodin on the Movement of the Head Appendages^{1,2}

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The actual catenary feeding process consists of a sequence of activities which takes place before the time plant particles are swallowed by phytophagous insects (SCHOONHOVEN, 1968). The physiology underlying the host preference behaviour, especially the muscles involved in the feeding behaviour and output pattern during mandibular movement in the larvae of *Callopistria repleta* was revealed by WAGO and YAMAMOTO (1978).

Measurement of mandibular movements of phytophagous insect larvae is often useful in biological, pharmacological, and toxicological studies (SHIMIZU

et al., 1980). Recently SHIMIZU et al. (1981 a, b) studied the effect of chlordimeform and its analogues on mandibular movements when applied on the mouthparts of the last instar larvae and prepupae of the cabbage armyworm, *Mamestra brassicae*.

Information on different antifeeding ratios and the outward excitation symptoms of behavioural studies (ANTONIOUS and SAITO, 1983) confirmed that the site of action of clerodin involved in the stimulus transduction process in some gustatory receptor cells of the sensilla basiconica of the maxillary palps, and the primary site of action of chlordimeform was the hypopharynx. Based on the sensitivities of various chemoreceptors, the following study was made to clarify the effect of topical application on some chemoreceptors and the resulting movements of the other head appendages.

Fifth instar larvae of the tobacco cutworm deprived of food for 4 hr before application were used. Chlordimeform and clerodin were prepared in a solvent mixture of acetone, Tween-20 and distilled water (5:5:90 v/v). The larvae were fixed, ventral side (sternites) up, to a piece of plastic foam plate with three loops of steel around the neck, thorax and posterior abdominal segments. A drop of 0.00466 μ l of the antifeedant solution was topically applied to each target using the previously mentioned glass microsyringe, a microapplicator

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Table 1. Movements of the various mouthparts and antennae after topical application (each value indicates mean of 10 individuals $\pm$ SD)

Tested antifeedant	Target of application	Elapsed time following application	Response (rate of movement)		
			Mandibles	Maxillary palps + Labium + Hypopharynx	Antennae
Chlordimeform 8,000 ppm	Hypopharynx	1 min	0.0	0.0	0.0
		3 do.	0.0	19.3 $\pm$ 2.2	0.0
		7 do.	8.9 $\pm$ 2.2	13.6 $\pm$ 3.1	10.2 $\pm$ 2.6
		10 do.	17.0 $\pm$ 3.2	11.2 $\pm$ 2.8	3.7 $\pm$ 2.9
	Top of the maxillary palps	1 min	0.0	0.0	0.0
		3 do.	0.0	0.0	0.0
		7 do.	3.5 $\pm$ 1.6	4.2 $\pm$ 1.5	8.6 $\pm$ 2.8
		10 do.	5.1 $\pm$ 1.4	8.2 $\pm$ 2.1	2.3 $\pm$ 1.9
	Antennae	1 min	0.0	0.0	0.0
		3 do.	0.0	0.0	0.0
		7 do.	0.0	0.0	15.7 $\pm$ 3.9
		10 do.	2.7 $\pm$ 1.8	1.8 $\pm$ 1.3	6.2 $\pm$ 2.6
Clerodin 125 ppm	Hypopharynx	1 min	0.0	0.0	0.0
		3 do.	0.0	0.0	0.0
		7 do.	0.0	0.0	0.0
		10 do.	10.1 $\pm$ 1.3	15.3 $\pm$ 6.3	0.0
	Top of the maxillary palps	1 min	0.0	0.0	0.0
		3 do.	0.0	0.0	0.0
		7 do.	0.0	5.2 $\pm$ 2.9	0.0
		10 do.	7.7 $\pm$ 2.1	10.9 $\pm$ 3.5	0.0
	Antennae	1 min	0.0	0.0	0.0
		3 do.	0.0	0.0	0.0
		7 do.	0.0	3.1 $\pm$ 1.6	0.0
		10 do.	5.2 $\pm$ 2.0	0.0	0.0

Solvent: Treated larvae showed no movement when solvent alone was applied.

apparatus and a dissecting microscope (ANTONIOUS and SARRO, 1983). The movement rates of various mouth parts and antennae were counted with a manual counter and stop watch. Control larvae were treated with the same drop of solvent mixture.

Rates of movement of the treated targets, neighbouring mouth parts and antennae are shown in Table 1. The data showed that the most sensitive target of chlordimeform was the hypopharynx as it responded earlier and stronger than other targets (19.3/min) after 3 min of application. Movement of the hypopharynx lasted for 10 min after application. Its excitation movements were accompanied by excitation movements in the maxillary palps, labium, labial palps and the spinneret. Treating the hypopharynx generated movement of the mandibles 7 min after application (8.9/min) and the rate of movement increased (17.0/min)

10 min after application.

The same treatment showed a clear excitatory effect on antennal movement 7 min after application (10.2/min) and the rate of movement decreased suddenly 10 min (3.7/min) later.

In comparison, treating the two maxillary palps with chlordimeform had very little effect on the movement of the two mandibles, as shown by the low frequency value (3.5/min). The same treatment showed no effect on the antennae until 7 min had elapsed after application; then antennal movement was evoked (8.6/min), but soon disappeared.

The antennae showed a high degree of movement when treated 7 min after (15.7/min) and 6.2/min after 10 min of application of chlordimeform. On the other hand, clerodin applied on the hypopharynx showed a remarkable effect on the movement of the mandibles (10.1/min) 10 min after

application. The same treatment also showed a strong effect on the movement of the labium hypopharynx maxillary complex (15.3/min), without any effect on antennal movement. Treating the top of the maxillary palps with clerodin had a weak effect on the complex structure, but the rate of movement became higher 10 min after application (10.9/min). Treatment of antennae with clerodin showed a very weak effect on the rate of mandibular movement and other mouth parts, and had no effect on the antennae themselves.

The movement of both mandibles was characterized as horizontal, while the maxillary palps always responded with irregular movements. Antennal movements were characteristically tremors.

The results obtained from the present investigation are in full agreement with the antifeeding and behavioural studies of the previous topical application: the most sensitive action site of chlordimeform is the hypopharynx and for clerodin it is the gustatory sensilla basiconica located on the top of both maxillary palps (ANTONIOUS and SAITO, 1983).

The physiological explanation of the observed movement in the various responding mouth parts and antennae is that the chemoreceptors of the treated targets showed different sensitivity to the

applied materials. The evoked movements were integrated from the nerves of the affected chemoreceptors to the CNS which in return integrated this effect to the other peripheral nerves arising from it and innervated other organs.

The above argument supports the data reported by SHIMIZU et al. (1981 b) who reported that the antifeeding activity of chlordimeform results from continuous repetitive bursts of mandibular movements (CBMM) in *Mamestra brassicae*. They reported that this CBMM was not evoked when an aqueous solution of chlordimeform was placed topically on the antennae of prepupal insects.

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Sequence of Predatory Behavior of the Ladybeetle, *Coccinella septempunctata* L. (Coleoptera: Coccinellidae) on the Green Peach Aphid, *Myzus persicae* SULZER (Homoptera: Aphididae)¹

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As ladybeetles are effective predators of aphids and scales (HÄMÄLÄINEN et al., 1975), many studies have been conducted on their feeding behavior (cf. HODEK, 1973). However, little information is available on the sequence analysis and the involve-

ment of stimuli in the predatory behavior of coccinellids. Since each event in a behavioral sequence may be governed by different kinds of stimuli (CURIO, 1976), a description of predatory behavior is necessary to analyze the stimuli involved in that behavior.

Ladybeetles, *Coccinella septempunctata* L., were reared on an excess of daily food, the green peach aphid, *Myzus persicae* SULZER, under $25 \pm 3^\circ\text{C}$ and 16 hr photophase from egg to adult. Aphids were reared on potted cabbage plants under the same conditions of temperature and light as the beetles.

To observe the predatory behavior of the ladybeetle, an observation apparatus composed of a gray vinyl chloride cylinder (30 cm in diameter and 5 cm in height) resting on a white paper overlaid a transparent acryl plate, was used. The top of the cylinder was covered with another transparent

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