EFFECT OF HEXAFLUMURON ON FEEDING RESPONSE AND REPRODUCTION OF ADULT BOLLWORM

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Abstract

A commercial formulation of the insecticide hexaflumuron (Consult® 100 EC, Dow AgroSciences) not registered for use in the U.S. was evaluated for its potential as a toxicant and reproduction inhibitor for control of adult bollworm, *Helicoverpa zea* (Boddie), with feeding attractants and stimulants. When mixed with 2.5 M sucrose and ingested by sex pheromone trap-captured males, hexaflumuron had significantly different 24- and 48-hour lethal concentration (LC_{50}'s) of 262.94 and 104.68 ppm (ai wt:vol), respectively. Compared with other insecticides previously evaluated, hexaflumuron has low oral toxicity and is slow-acting. Feeding response evaluations at lethal and sublethal concentrations ranging from 1 to 10000 ppm with sex pheromone trap-captured males and laboratory-reared males and females indicated that gustatory responses were significantly reduced at concentrations above 10 ppm compared with sugar solutions without insecticide. The proboscis extension response was significantly reduced when hexaflumuron was mixed with 1.0 M sucrose at 50 ppm. There was no significant reduction in proboscis extension response between test solutions and control when 2.5 M sucrose was used. Percent larval hatch of eggs oviposited by laboratory-reared females during 3 consecutive days was drastically reduced at concentrations of 10 ppm and below when compared to eggs oviposited by females fed only sugar. Mean numbers of spermatophores per treated female were not consistently reduced compared to untreated females indicating that mating did not significantly contribute to reduction in larval hatch of eggs. When treated laboratory-reared males were paired with untreated females, there was no significant effect on frequency of mating or larval hatch of eggs; therefore, the effect of hexaflumuron on larval hatch of eggs is only on females. Based on these results, the formulation of hexaflumuron tested has potential for use as a reproduction inhibitor for adult control of bollworm with feeding attractants and stimulants. A critical assessment of hexaflumuron's potential under field conditions is needed before additional studies on changes in formulation and feeding stimulant to overcome feeding inhibition are warranted.

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Introduction

As part of our research on the development of adult control technology for bollworm, *Helicoverpa zea* (Boddie), with feeding attractants and stimulants, we have been evaluating insecticides for feeding compatibility and for efficacy in killing adults directly or inhibiting reproduction when ingested (Clemens 1996, Lopez et al. 1997, Lopez and Latheef 1998, 1999a, 1999b). The aim for developing this technology is to reduce the amount of toxicant and to use more selective toxicants to effect control which are important criteria for a sustainable cotton production system. One of the toxicants that may have potential for use in this adult control technology is hexaflumuron. It is currently being marketed as the active ingredient in a bait system called Sentricon® (Dow AgroSciences, Indianapolis, IN) for control of termites. Hexaflumuron is a benzoylphenylurea that inhibits chitin synthesis and mainly acts as an ovicide and larvicide (Retnakaran and Wright 1987). It has been reported to have contact toxicity to adults of cotton leafworm, *Spodoptera littoralis* (Boisduval) and cause decreased larval hatch of eggs oviposited by exposed adults (Hossain et al. 1996). Horowitz et al. (1992) also reported up to 80% suppression of larval hatch of eggs dipped in a solution containing 50 ppm hexaflumuron. Feeding of newly eclosed adult beet armyworm, *Spodoptera exigua* (Hübner), on 10% honeywater containing 100 ppm of chlorfluazuron, an acylurea chitin synthesis inhibitor, resulted in only 16% hatch of eggs oviposited (Laecke et al. 1989). Additional research is needed to evaluate the effect of these types of insecticides on other adult noctuids especially when used in conjunction with feeding attractants/stimulants. The objectives of the research reported here were to determine the toxicity of hexaflumuron mixed with a feeding stimulant to adult bollworm when ingested and the effects of lethal or sublethal concentrations on feeding response (both proboscis extension and gustatory) and reproduction.

Materials and Methods

Chemical - Hexaflumuron was obtained as Consult® 100 EC containing 100 gm ai/l (0.8344 lb/gal) from Dow AgroSciences, King's Lynn, Norfolk, England. This formulation is currently not registered for use on field crops in the U.S. Test concentrations were prepared (ppm ai wt:vol) in 1.0 and 2.5 M sucrose (Sigma, St. Louis, MO) solutions.

Insects - Both sex pheromone trap-captured males and laboratory-reared females and males were used. Sex pheromone trap-captured males were captured using 75-50 Texas pheromone traps (Hartstack et al. 1979) baited with laminated plastic Zealures® (Hercon Environmental, Emigsville, PA). The traps were operated in an agricultural area in the Brazos River Valley close to College Station, TX.

Only males trapped the previous night that had been given deionized water *ad libitum* before testing were used. Laboratory-reared bollworm moths were obtained from a culture maintained as described by Lopez and Latheef (1998). Pupae were sexed and placed separately in 3.8 l (1 gal) glass jars without food for emergence. Females and males used for testing emerged overnight.

Determination of Lethal Concentration (LC) - A series of hexaflumuron concentrations in 2.5 M sucrose and 2.5 M sucrose alone as control were fed to sex pheromone trap-captured males. Groups of ten males that had fed on the same concentration were placed in 0.92 l (1 qt) glass jars without food and checked for mortality at 24 and 48 hours. A male was considered dead when it could not right itself when upside down.

Determination of Proboscis Extension Response - Proboscis extension response of sex pheromone trap-captured males was evaluated at night in an insectary under red light. A series of sublethal concentrations of hexaflumuron in 1.0 and 2.5 M sucrose and 1.0 and 2.5 M sucrose alone as control were placed in the wells of porcelain spot plates and the moths were allowed to contact test solutions with their front tarsi. The moths were observed for a positive proboscis extension response that required contact of the test solution with the proboscis. A total of 10 replicates were conducted, each consisting of the response of 10 males per test solution.

Determination of Gustatory Response - Solutions were weighed on an electronic balance before and after feeding of laboratory-reared females and males. Adults were mounted individually on a feeding apparatus and were offered the test solutions contained in a disposable polystyrene microcentrifuge tube (0.5 ml). Control solutions exposed simultaneously to the same experimental conditions were used to account for evaporation loss.

Determination of Reproductive Effects of Sublethal Concentrations on Laboratory-Reared Females and Males - Three different tests were conducted. Tests 1 and 2 evaluated the effect of hexaflumuron on reproduction of treated females mated with untreated males and Test 3 of treated males mated with untreated females. In Test 1, hexaflumuron concentrations evaluated were 0, 1, 10, 100, 1000, and 10000 ppm. Tests 2 and 3 were conducted with hexaflumuron concentrations of 0.0, 2.5, 5.0, 10.0, 25.0, and 50.0 ppm. Females and males were fed test concentrations within 24 hours of emergence and were compared with control females and males fed only 2.5 M sucrose. The amount ingested in one half hour by each female and male was determined as described for gustatory response. Each treated female or male was paired with an untreated female or male in a 0.92 l (1 qt) glass jar. Paper toweling was used to close the mouth of the jar and a towel strip suspended from the top served as a resting and ovipositional substrate. Moths were provided a 10% sucrose solution. Moths were moved to clean jars after the 2nd day and each day thereafter for 3 days. Previous research has shown that for laboratory-reared females under laboratory conditions, a major proportion of a female's reproductive potential is expressed during this 3-day evaluation period. Paper toweling containing a sample of up to about 30 eggs was collected from each jar and placed in sealed plastic cups. Egg samples were checked for larval hatch 2 days after collection for 3 consecutive days. At the end of each test or before if the females died or were *in copula*, females were dissected to determine the number of spermatophores in the bursa copulatrix. Eggs from unmated females were not used to determine larval hatch.

Data Analysis – Lethal concentration data were calculated with the LeOra software (LeOra 1987). All other data were analyzed using the GLM procedure of SAS (SAS 1998) and significantly different means were separated with the Least Significant Difference Test with $p = 5\%$.

Results and Discussion

Hexaflumuron as formulated was found to be toxic to sex pheromone trap-captured male bollworms (Table 1). The LC_{50} of 262.94 ppm at 24 hours was significantly different from 104.68 ppm at 48 hours based on the lack of overlap of the 95% CI values. This significant difference between the 24 and 48 hour LC_{50}s indicates that hexaflumuron is a relatively slow-acting insecticide. Compared to a number of other insecticides that have been evaluated in the same manner (Clemens 1996, Lopez et al. 1997), hexaflumuron has relatively low oral toxicity. Based on the LC_{10}s of 75.38 and 27.94 ppm at 24 and 48 hours, respectively, sublethal concentrations would need to be below about 25 ppm.

Evaluation of sublethal concentrations of hexaflumuron in 1.0 and 2.5 M sucrose for effect on proboscis extension response of sex pheromone trap-captured males showed that the only concentration that significantly reduced response compared to the sucrose solutions alone was 50.0 ppm in 1.0 M sucrose (Table 2). Because proboscis extension is the initial response necessary for feeding, these results indicate that hexaflumuron could be used at sublethal concentrations of 25 ppm and below in the field and not interfere with initiation of feeding.

The gustatory response of laboratory-reared female bollworms evaluated in Test 1 was significantly reduced compared to 2.5 M sucrose alone at concentrations of 10 ppm and above (Table 3). Reductions in gustatory response became more pronounced at concentrations of 100 ppm and above. Although the inhibitory effect of hexaflumuron concentration on gustation shown here is for laboratory-reared females, it is likely that gustatory response inhibition

also affected the LC values for the sex pheromone trap-captured males. Specific research on the effect of hexaflumuron concentration and formulation on gustation of field-collected bollworm moths is needed. Based on feeding inhibition at higher concentrations, hexaflumuron in the formulations evaluated will probably not be effective in an adult control system aimed at killing the adults directly.

Test 1 results on the effect of hexaflumuron on percent larval hatch of eggs oviposited by females fed concentrations of 1, 10, 100, and 1000 ppm showed that statistically significant reductions compared to the control for all 3 days of evaluation were caused by concentrations as low as 1 ppm of hexaflumuron (Table 4). Data were not obtained for 10000 ppm because females died soon after ingestion. The largest decrease in percent larval hatch of eggs was observed at 10 ppm with no significantly higher reductions at 100 and 1000 ppm. It is likely that gustatory response inhibition at hexaflumuron concentrations of 10 ppm and above (Table 3) influenced the reduced effects on larval hatch of eggs at the 100 and 1000 ppm concentrations. In view of the inhibitory effects of hexaflumuron on feeding response at concentrations of 10 ppm and above, the dramatic reduction in larval hatch of eggs observed at 10 ppm concentrations and below was very significant.

Mating frequency of treated females in Test 1 was significantly reduced compared to the control at the 10 and 1000 ppm hexaflumuron concentrations (Table 5). Lack of a significant effect on mating frequency at the 100 ppm concentration compared to the control indicates that the effect on mating inhibition was not consistent relative to hexflumuron concentration.

Test 2, in which 0, 2.5, 5.0, 10.0, 25.0, and 50.0 ppm hexaflumuron concentrations were evaluated, was conducted to better assess the effects of hexaflumuron concentrations on feeding response and reproduction. Gustatory response was significantly reduced compared to 2.5 M sucrose alone at all test concentrations except 5.0 ppm (Table 6). These results were comparable to results obtained in Test 1 for 10 ppm, but were inconsistent for concentrations below 10 ppm. There was no significant difference between control and 5.0 ppm; however, the difference between 2.5 ppm and control was significant. Based on the results with concentrations of 25 ppm and higher in both tests, inhibition of gustatory response apparently levels off at the higher hexaflumuron concentrations.

Results of Test 2 on percent larval hatch of eggs oviposited by treated females (Table 7) were less consistent than those obtained in Test 1, probably because of the relatively small differences in hexflumuron concentration that were evaluated especially from the standpoint of accurate mixing of test solutions. The effect of 2.5 ppm hexaflumuron on larval hatch of eggs in Test 2 did not show a concentration effect relative to the effect of 1.0 ppm in Test 1. Results with 5.0 ppm and higher for both tests indicate that concentrations as low as 5.0 ppm may be effective in dramatically reducing larval hatch of eggs oviposited by treated females.

There were no significant differences compared to control in the number of spermatophores per female relative to hexaflumuron concentration in Test 2 (Table 8). Therefore, it is apparent that the effects of hexaflumuron on reducing larval hatch of eggs are not the result of mating inhibition.

It would be extremely advantageous to use an insecticide in adult bollworm control technology with feeding attractants/stimulants that in addition to reducing larval hatch of eggs oviposited by treated females also has an effect on reproduction through the males. Test 3 was conducted to determine if hexaflumuron also affected reproduction of untreated females mated with treated males. Gustatory response of laboratory-reared males to hexaflumuron concentrations was similar to that for the females evaluated in Test 2, except that variation was considerably higher for the males than for the females (Table 9).

Results of Test 3 on percent larval hatch of eggs oviposited (Table 10) and number of spermatophores per untreated female (Table 11) indicated that ingestion of hexaflumuron at concentrations which have an effect on the females did not affect reproduction of untreated females mated with treated males.

A major concern for the use of hexaflumuron in an adult control system with feeding attractants/stimulants is the inhibition of feeding at concentrations slightly higher than those that cause major reductions in larval hatch of eggs oviposited by treated females. This problem may be overcome by modifications in the formulation of hexaflumuron or in the feeding stimulant. A commercial formulation of hexaflumuron was used in these studies because this is more practical for field use than the technical material. Evaluation of other hexaflumuron formulations will depend on its potential for registration and efficacy for use on field crops in the U. S. An evaluation of the effect on gustatory response of changing the concentration of the feeding stimulant from 2.5 to 1.0 M did indicate that inhibition of gustatory response could be reduced (Table 12). Additional research will be needed along these lines to determine if the inhibitory effect of hexaflumuron on feeding can be reduced by manipulation of the feeding stimulant.

Conclusions

Hexaflumuron has potential for use as reproduction inhibitor in an adult control system using feeding attractants/stimulants because it causes dramatic reductions of larval hatch of eggs oviposited by females that ingest it at relatively low concentrations. A problem with its use is the possible inhibition of the feeding response (both proboscis extension and gustatory) at concentrations slightly higher than those which cause inhibition of larval hatch of eggs. It may be possible to overcome this problem by changes in the formulation or feeding stimulant; however, a very intensive assessment of hexaflumuron's potential for use in adult control technology under field conditions is necessary before evaluating changes in the formulation or the feeding stimulant.

Disclaimer

Mention of a commercial or proprietary product does not constitute an endorsement for its use by the U. S. Department of Agriculture.

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Table 1. Lethal concentration (ppm ai wt:vol) data (24- and 48-hour) for the toxicity of hexaflumuron to sex pheromone trap-captured male bollworm when mixed with 2.5 M sucrose and ingested.[1]

	No. Hours after Feeding	
Regression Statistics	**24**	**48**
Slope (±SE)[2]	2.362 (±0.244)	2.234 (±0.238)
χ^2(df)[2]	7.138 (3)	8.260 (3)
LC10(ppm)[2] (95% lower-upper limits)	75.38 a (18.59 – 123.41)	27.94 a (3.88 – 55.03)
LC50(ppm)[2] (95% lower-upper limits)	262.94 a (176.75 – 454.70)	104.68 b (51.79 – 155.99)
LC90(ppm)[2] (95% lower-upper limits)	917.18 a (507.28 – 5550.31)	392.24 a (246.83 – 1236.72)

[1]Based on 600 males.

[2]Calculated using POLO-PC (LeOra Software, 1987). LC values in the same row followed by different letters are significantly different based on the lack of overlap in the 95% lower and upper limits.

Table 2. Percent proboscis extension response of sex pheromone trap-captured male bollworms to different concentrations (ppm ai wt:vol) of hexaflumuron mixed in 1 and 2.5 M sucrose solutions and to 1 and 2.5 M sucrose alone.

	Mean Percent (± SE) Positive Proboscis Extension Response to Indicated Sucrose Concentrations	
Concentration (ppm)	1.0 M[2]	2.5 M[2]
0.0	81(±4) a	72(±7) ab
2.5	67(±6) ab	64(±8) ab
5.0	72(±6) ab	73(±6) ab
10.0	63(±6) ab	76(±7) a
25.0	68(±8) ab	67(±5) ab
50.0	54(±7) b	57(±5)

[1]Based on ten replications of ten insects each per concentration.
[2]Means in the same column followed by different letters are significantly different based on the Least Significance Difference Test with $\alpha = 0.05$, LSD in percent were : 1.0 M = 18.7 and 2.5 M = 18.4.

Table 3. Gustatory response (mg) of laboratory-reared female bollworms to different concentrations (ppm ai wt:vol) of hexaflumuron mixed with 2.5 M sucrose and 2.5 M sucrose alone[1].

Concentration (ppm)	Mean No. of Mg (± SE) Ingested[2]
0	83.7 (±5.3) a
1	73.0 (±5.3) ab
10	62.9 (±4.4) b
100	41.0 (±4.4) c
1000	15.2 (±1.3) d
10000	12.0 (±1.8) d

[1]Based on amount of each test concentration ingested by 18 females.
[2]Means followed by different letters are significantly different according to the Least Significant Difference Test with $\alpha = 0.05$, LSD = 11.4 mg.

Table 4. Mean percent (± SE-N) larval hatch of eggs oviposited over a three-day period by laboratory-reared female bollworms fed various concentrations of hexaflumuron mixed with 2.5 M sucrose and 2.5 M sucrose alone (Test 1).

Mean percent (± SE-N) Larval Hatch for Indicated Concentrations (ppm)[1]				
0	1	10	100	1000
		Day 1		
81.6 a (±2.4 -17)	41.9 b (±8.4 -15)	8.5 c (±3.9 -16)	11.6 c (±6.0 -17)	2.7 c (±1.8 -10)
		Day 2		
84.3 a (±2.6 -17)	55.3 b (±6.9 -16)	8.6 c (±5.8 -15)	4.4 c (±4.2 -17)	0.0 c (±0.0 -10)
		Day 3		
80.8 a (±3.6 -17)	33.8 b (±8.5 -14)	0.0 c (±0.0 -15)	1.3 c (±1.3 -16)	0.0 c (±0.0 -9)
		Total		
81.9 a (±1.8 -17)	42.0 b (±6.8 -13)	5.8 c (±2.5 -15)	5.9 c (±2.7 -16)	1.1 c (±0.7 -9)

[1]Means in the same row followed by different letters are significantly different according to the Least Significant Difference Test with $\alpha = 0.05$. LSDs in percent were: Day 1 = 15.4, Day 2 = 14.11, Day 3 = 12.35, and Total = 10.14. N is the number of females evaluated.

Table 5. Mean number (± SE) of spermatophores per female for laboratory-reared female bollworms fed various concentrations of hexaflumuron mixed with 2.5 M sucrose and 2.5 M sucrose alone (Test 1).

Concentration (ppm)	No.	Mean No. (± SE) Spermatophores/Female [1]
0	17	3.06 ±0.18 a
1	16	2.38 ±0.27 ab
10	16	2.06 ±0.28 b
100	17	2.60 ±0.24 ab
1000	16	1.31 ±0.35 c

[1]Means followed by different letters are significantly different according to the Least Significant Difference Test with $\alpha = 0.05$, LSD = 0.75 spermatophores.

Table 6. Mean gustatory response (mg ± SE) of female laboratory-reared bollworms to various concentrations (ppm ai wt:vol) of hexaflumuron mixed in 2.5 M sucrose and 2.5 M sucrose alone (Test 2).

Concentration (ppm)	No.	Mean No (± SE) Mg Ingested
0.0	20	85.3 ±7.2 a
2.5	20	68.5 ±4.5 bc
5.0	20	76.8 ±5.1 ab
10.0	20	57.0 ±4.5 cd
25.0	20	43.9 ±3.4 d
50.0	20	42.7 ±5.3 d

Means followed by different letters are significantly different according to the Least Significant Difference Test with $\alpha = 0.05$, LSD = 14.3 mg.

Table 7. Mean percent (± SE-N) larval hatch of eggs oviposited over a three-day period by laboratory-reared female bollworms fed various concentrations (ppm ai wt:vol) of hexaflumuron mixed with 2.5 M sucrose and 2.5 M sucrose alone (Test 2).

Concentration (ppm)	Mean Percent Larval Hatch (± SE-N) for Indicated Day[1]			
	1	2	3	Total
0.0	75.8 a (±8.5-18)	79.4 a (±5.3-18)	84.3 a (±6.1-16)	80.8 a (±5.8-16)
2.5	72.4 a (±6.2-17)	69.7 a (±7.5-18)	70.0 b (±8.2-19)	69.8 a (±7.0-16)
5.0	28.7 b (±6.7-19)	10.2 b (±4.2-19)	0.0 c (±0.0-17)	13.5 b (±3.3-17)
10.0	20.4 bc (±7.5-18)	6.7 b (±5.1-18)	0.2 c (±0.2-17)	7.2 b (±3.2-15)
25.0	3.1 c (±1.6-19)	0.3 b (±0.3-19)	0.0 c (±0.0-17)	1.4 b (±0.7-16)
50.0	18.6 bc (±6.1-17)	5.5 b (±4.8-18)	4.5 c (±4.5-19)	9.8 b (±4.7 - 6)

[1]Means in the same column followed by different letters are significantly different according to the Least Significant Difference Test with $\alpha = 0.05$. LSDs in percent were: Day 1 = 17.9, Day 2 = 13.8, Day 3 = 12.6, and Total = 12.9. N is the number of females evaluated.

Table 8. Mean number (± SE) of spermatophores per female dissected from laboratory-reared female bollworms fed various concentrations (ppm ai wt:vol) of hexaflumuron mixed with 2.5 M sucrose and 2.5 M sucrose alone (Test 2).

Concentration (ppm)	No.	Mean No. (± SE) Spermatophores per Female[1]
0	18	2.56 (±0.23)
2.5	18	2.72 (±0.31)
5.0	18	2.72 (±0.28)
10.0	18	2.67 (±0.26)
25.0	19	2.58 (±0.21)
50.0	19	2.16 (±0.25)

[1]There were no significant differences between treatments based on the GLM procedure with $\alpha = 0.05$; $F = 0.70$, df = 5,104; $p = 0.621$.

Table 9. Gustatory response (mg ± SE) of laboratory-reared male bollworms fed various concentration of hexaflumuron mixed with 2.5 M sucrose and 2.5 M sucrose alone (Test 3).

Concentration (ppm)	No.	Mean No. Mg (± SE) Ingested[1]
0.0	6	92.8 (±12.9) a
2.5	6	47.3 (±8.4) c
5.0	6	72.4 (±7.2) ab
10.0	6	72.9 (±5.9) ab
25.0	6	56.9 (±5.9) bc
50.0	6	54.5 (±7.1) bc

[1]Means followed by different letters are significantly different according to the Least Significant Difference Test with $\alpha = 0.05$, LSD = 23.0 mg.

Table 10. Mean percent (± SE-N) larval hatch of eggs oviposited during a three-day period by untreated laboratory-reared female bollworms paired with laboratory-reared males fed various concentrations (ppm ai wt:vol) of hexaflumuron mixed with 2.5 M sucrose and 2.5 M sucrose alone (Test 3).

Mean Percent Larval Hatch (± SE-N) for Indicated Concentration (ppm)[1]					
0	2.5	5.0	10.0	25.0	50.0
Day 1					
71.9 (15.2 - 6)	66.7 (14.4 - 6)	78.7 (8.2 - 5)	87.1 (3.6 - 6)	82.4 (3.8 - 6)	79.9 (7.9 - 5)
Day 2					
72.9 (10.0 - 5)	70.1 (15.2 - 6)	82.3 (12.4 - 5)	81.2 (5.1 - 6)	88.5 (1.6 - 5)	82.0 (4.8 - 6)
Day 3					
70.2 (18.0 - 5)	76.3 (16.2 - 6)	86.0 (8.6 - 5)	83.7 (3.9 - 6)	84.4 (7.0 - 5)	74.0 (3.5 – 6)
Total					
69.7 (14.9 - 5)	71.1 (14.5 - 6)	82.2 (9.5 - 5)	83.8 (3.3 - 6)	85.1 (3.9 - 5)	82.1 (5.1 - 5)

[1]Means in the same row are not significantly different with $\alpha = 0.05$: Day 1 - $F = 0.54$, df = 5,28, $p = 0.7412$; Day 2 - $F = 0.49$, df = 5,28, $p = 0.7804$; Day 3 - $F = 0.34$, df = 5,27, $p = 0.8863$; Total – $F = 0.45$, df = 5,26, $p = 0.8117$.

Table 11. Mean number (± SE) of spermatophores per untreated laboratory-reared female bollworm paired with laboratory-reared males fed various concentrations (ppm ai wt:vol) of hexaflumuron mixed with 2.5 M sucrose or 2.5 M sucrose alone.

Concentration (ppm)	No.	Mean No. (± SE) Spermatophores per Female[1]
0.0	6	2.7 (±0.3)
2.5	6	2.8 (±0.3)
5.0	6	2.3 (±0.5)
10.0	6	3.0 (±0.4)
25.0	6	3.0 (±0.4)
50.0	6	2.7 (±0.5)

[1]Means are not significantly different between treatments based on the GLM procedure with $\alpha = 0.05$, E = 0.40, df = 5, $F = 0.8457$.

Table 12. Gustatory response (mg ± SE) of laboratory-reared female and male bollworms to various concentrations (ppm ai wt:vol) of hexaflumuron mixed with 1.0 and 2.5 M sucrose or 1.0 and 2.5 M sucrose alone.

Concentration (ppm)	Mean No. Mg (± SE) Ingested[1]			
	1.0 m		2.5 m	
	Female	Male	Female	Male
0	113.1 aA (±11.6)	102.3 aA (±10.9)	70.6 aB (±8.7)	77.1 aB (±6.1)
10	102.4 aA (±9.5)	76.7 bB (±5.4)	54.1 abC (±6.1)	46.0 bC (±6.5)
25	61.9 bAB (±7.2)	79.5 bA (±8.7)	46.8 bBC (±6.9)	33.6 bC (±3.9)

[1]Means within each column followed by different lower case letters are significantly different according to the Least Significant Difference Test with $\alpha = 0.05$, LSD = 22.0 mg. Means within each row followed by different upper case letters are significantly different according to the Least Significant Difference Test with $\alpha = 0.05$, LSD = 22.0 mg.