Seasonal Distributions, Relative Abundances and Sexual Communication of the Plusiinae (Lepidoptera: Noctuidae) of Louisiana Soybean Ecosystems.

Arthur Randall Alford
Louisiana State University and Agricultural & Mechanical College

Follow this and additional works at: https://digitalcommons.lsu.edu/gradschool_disstheses

Recommended Citation
https://digitalcommons.lsu.edu/gradschool_disstheses/3469
INFORMATION TO USERS

This was produced from a copy of a document sent to us for microfilming. While the most advanced technological means to photograph and reproduce this document have been used, the quality is heavily dependent upon the quality of the material submitted.

The following explanation of techniques is provided to help you understand markings or notations which may appear on this reproduction.

1. The sign or "target" for pages apparently lacking from the document photographed is "Missing Page(s)". If it was possible to obtain the missing page(s) or section, they are spliced into the film along with adjacent pages. This may have necessitated cutting through an image and duplicating adjacent pages to assure you of complete continuity.

2. When an image on the film is obliterated with a round black mark it is an indication that the film inspector noticed either blurred copy because of movement during exposure, or duplicate copy. Unless we meant to delete copyrighted materials that should not have been filmed, you will find a good image of the page in the adjacent frame.

3. When a map, drawing or chart, etc., is part of the material being photographed the photographer has followed a definite method in "sectioning" the material. It is customary to begin filming at the upper left hand corner of a large sheet and to continue from left to right in equal sections with small overlaps. If necessary, sectioning is continued again—beginning below the first row and continuing on until complete.

4. For any illustrations that cannot be reproduced satisfactorily by xerography, photographic prints can be purchased at additional cost and tipped into your xerographic copy. Requests can be made to our Dissertations Customer Services Department.

5. Some pages in any document may have indistinct print. In all cases we have filmed the best available copy.
ALFORD, ARTHUR RANDALL

SEASONAL DISTRIBUTIONS, RELATIVE ABUNDANCES AND SEXUAL COMMUNICATION OF THE PLUSIINAE (LEPIDOPTERA: NOCTUIDAE) OF LOUISIANA SOYBEAN ECOSYSTEMS

The Louisiana State University and Agricultural and Mechanical Col. PH.D. 1980
PLEASE NOTE:

In all cases this material has been filmed in the best possible way from the available copy. Problems encountered with this document have been identified here with a check mark ✓.

1. Glossy photographs ✓
2. Colored illustrations
3. Photographs with dark background ✓
4. Illustrations are poor copy
5. Print shows through as there is text on both sides of page
6. Indistinct, broken or small print on several pages throughout
7. Tightly bound copy with print lost in spine
8. Computer printout pages with indistinct print
9. Page(s) lacking when material received, and not available from school or author
10. Page(s) seem to be missing in numbering only as text follows
11. Poor carbon copy
12. Not original copy, several pages with blurred type
13. Appendix pages are poor copy
14. Original copy with light type
15. Curling and wrinkled pages
16. Other
Seasonal Distributions, Relative Abundances and Sexual Communication of the Plusiinae (Lepidoptera: Noctuidae) of Louisiana Soybean Ecosystems

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy in

The Department of Entomology

by

Arthur Randall Alford
B.S., University of Southern Mississippi, 1974
M.S., Louisiana State University, 1976
May 1980
ACKNOWLEDGMENTS

I would like to express my sincere gratitude to my major professor, Dr. Abner M. Hammond, Jr., for his assistance and consultation during this study and during the preparation of this manuscript. Appreciation is also due to Drs. L. D. Newsom, J. B. Graves, J. P. LaFage, J. T. Caprio and P. E. Schilling for their assistance as members of my graduate committee.

Special thanks go to the graduate students and student workers who helped with the field sampling and laboratory rearing which were vital to the study. I am especially grateful to Larry Stewart and Deborah Babcock of the Experimental Statistics Department for their valuable time and consultation. And finally, none of this would have been possible without the financial support provided through a graduate research assistantship by the Department of Entomology.

My most sincere appreciation is due my wife, Susan, and mother and father for their encouragement and support throughout this study and my entire student career.
TABLE OF CONTENTS

ACKNOWLEDGMENTS ................................................. ii
TABLE OF CONTENTS ................................................. iii
LIST OF TABLES ................................................. iv
LIST OF FIGURES ................................................. v
ABSTRACT ................................................... viii

CHAPTER I
Plusiinae Populations in Louisiana Soybean Ecosystems as
Determined with Looplure-baited Traps ........................ 1

Abstract ................................................... 2
Introduction ............................................... 3
Materials and Methods .................................... 5
Results ................................................... 7
Discussion ................................................. 35
Literature Cited .......................................... 38

CHAPTER II
Pheromone Trap Capture Rates as Population Indicators of the
Soybean Looper, *Pseudoplusia includens* (Walker) ......... 41

Abstract ................................................... 42
Introduction ............................................... 43
Materials and Methods .................................... 46
Results ................................................... 50
Discussion ................................................. 56
Literature Cited .......................................... 60

CHAPTER III
Field and Laboratory Concentration Evaluation of 3 Plusiine
Species to Looplure ............................................ 64

Abstract ................................................... 65
Introduction ............................................... 66
Materials and Methods .................................... 69
Results and Discussion .................................... 76
Literature Cited .......................................... 84

APPENDIX ....................................................... 87

VITA ........................................................... 97
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CHAPTER II</strong></td>
<td></td>
</tr>
<tr>
<td>1. Correlation coefficients (r) and coefficients of determination (r^2) for adult and larval (P. ) includens populations relationships in 3 Louisiana soybean ecosystems</td>
<td>53</td>
</tr>
<tr>
<td>2. Linear regression equations for 1977 and 1978 adult and larval (P. ) includens populations relationships</td>
<td>55</td>
</tr>
<tr>
<td><strong>CHAPTER III</strong></td>
<td></td>
</tr>
<tr>
<td>1. Sites monitored and number of concentrations evaluated for 3 soybean growing seasons in Louisiana</td>
<td>73</td>
</tr>
<tr>
<td>2. Mean capture rates of 3 plusiine species at 4 concentrations of synthetic sex pheromone in Louisiana soybean ecosystems</td>
<td>77</td>
</tr>
<tr>
<td>3. Calculated thresholds of response to synthetic sex pheromone and mean response to standard dosage (1 ug) of 3 plusiine species</td>
<td>78</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

**Figure** | **Page**
---|---

**CHAPTER I**

1. Sampling sites of plusiine survey designated S (southern — Niblett), SC (south central — Krotz Springs), NC (north central — Bunkie) ................. **6**

2a. Mean capture rate of male *P. includens* at Niblett (southern site) during 1977 ............... **8**

2b. Mean capture rate of male *P. includens* at Niblett (southern site) during 1978 ............... **9**

3a. Mean capture rate of male *P. includens* at Krotz Springs (south central site) during 1977 ............... **10**

3b. Mean capture rate of male *P. includens* at Krotz Springs (south central site) during 1978 ............... **11**

4a. Mean capture rate of male *P. includens* at Bunkie (north central site) during 1977 ............... **13**

4b. Mean capture rate of male *P. includens* at Bunkie (north central site) during 1978 ............... **14**

5a. Mean capture rate of male *T. ni* at Niblett (southern site) during 1977 ............... **15**

5b. Mean capture rate of male *T. ni* at Niblett (southern site) during 1978 ............... **16**

6a. Mean capture rate of male *T. ni* at Krotz Springs (south central site) during 1977 ............... **17**

6b. Mean capture rate of male *T. ni* at Krotz Springs (south central site) during 1978 ............... **18**

7a. Mean capture rate of male *T. ni* at Bunkie (north central site) during 1977 ............... **20**

7b. Mean capture rate of male *T. ni* at Bunkie (north central site) during 1978 ............... **21**

8a. Mean capture rate of male *R. ou* at Niblett (southern site) during 1977 ............... **22**

8b. Mean capture rate of male *R. ou* at Niblett (southern site) during 1978 ............... **23**
<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>9a. Mean capture rate of male R. ou at Krotz Springs (south central site) during 1977</td>
<td>24</td>
</tr>
<tr>
<td>9b. Mean capture rate of male R. ou at Krotz Springs (south central site) during 1978</td>
<td>25</td>
</tr>
<tr>
<td>10a. Mean capture rate of male R. ou at Bunkie (north central site) during 1977</td>
<td>26</td>
</tr>
<tr>
<td>10b. Mean capture rate of male R. ou at Bunkie (north central site) during 1978</td>
<td>27</td>
</tr>
<tr>
<td>11a. Mean capture rate of male T. oxygramma at Niblett (southern site) during 1977</td>
<td>28</td>
</tr>
<tr>
<td>11b. Mean capture rate of male T. oxygramma at Niblett (southern site) during 1978</td>
<td>29</td>
</tr>
<tr>
<td>12a. Mean capture rate of male T. oxygramma at Krotz Springs (south central site) during 1977</td>
<td>30</td>
</tr>
<tr>
<td>12b. Mean capture rate of male T. oxygramma at Krotz Springs (south central site) during 1978</td>
<td>31</td>
</tr>
<tr>
<td>13a. Mean capture rate of male T. oxygramma at Bunkie (north central site) during 1977</td>
<td>33</td>
</tr>
<tr>
<td>13b. Mean capture rate of male T. oxygramma at Bunkie (north central site) during 1978</td>
<td>34</td>
</tr>
</tbody>
</table>

**CHAPTER II**

1. Sampling sites of *P. includens* adult and larval populations study designated S (southern -- Niblett), SC (south central -- Krotz Springs), N (northern -- Bunkie) . . . . . . . . 48
2. Mean capture of *P. includens* adult males and larvae at Bunkie, La.(northern site) during 1977 . . . . . . . . 51
3. Mean capture of *P. includens* adult males and larvae at Bunkie, La.(northern site) during 1978 . . . . . . . . 52

**CHAPTER III**

1. Sampling sites included in field trapping evaluation of sex pheromone concentrations designated S (southern -- Niblett), SC (south central -- Krotz Springs), C (central -- Bunkie) and N (northern -- Bonita) . . . . . . . . 70
<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. EAG amplitude vs log concentration of looplure for male <em>P. includens</em> (eye-fitted curve)</td>
<td>79</td>
</tr>
<tr>
<td>3. EAG amplitude vs log concentration of looplure for male <em>T. ni</em> (eye-fitted curve)</td>
<td>80</td>
</tr>
<tr>
<td>4. EAG amplitude vs log concentration of looplure for male <em>R. ou</em> (eye-fitted curve)</td>
<td>81</td>
</tr>
</tbody>
</table>
ABSTRACT

An adult population survey of 4 species of the noctuid subfamily Plusiinae was conducted in soybean ecosystems of south, south central and north central Louisiana. Sticky-traps baited with the synthetic sex pheromone (Z)-7-dodecen-l-ol acetate, or looplure, were used as the sampling tools for 2 soybean growing seasons. The soybean looper Pseudoplusia includens (Walker) reached the highest densities of the plusiine complex with 4 and 5 generations detected in the southern and central regions of the state. Moth density was greatest at Krotz Springs (south central site) during 1977 and 1978; the lowest levels were detected at Niblett (southern site). Males were collected at the southernmost site on or before the time of initial capture at either of the more northern locations. Initial captures occurred in mid-June (the first sampling period) at all 3 locations during 1977; however, in 1978 adults were initially captured in mid-June at Niblett and in early August at Krotz Springs and Bunkie. Highest levels of capture occurred in September at all sites during both years. Although Rachiplusia ou (Guenee) were found to contribute considerably to the plusiine population in June, adult densities were quite low during the later summer months. Trichoplusia ni (Hubner) and T. oxygramma (Geyer) seldom attained high levels at any location.

Pheromone traps baited with 1000 µg of looplure were used in the assessment of population densities of adult P. includens. Estimates of adult density in the 3 soybean ecosystems were used to predict

viii
subsequent larval population densities at the 3 locations for the 2 growing seasons; simple linear regression equations were generated from these data. Regression coefficients increased with a northward progression during 1977, but low correlation coefficients existed between the adult and larval populations for all sites. Substantially higher correlation coefficients were determined for 1978, but the southern site unexpectedly exhibited the highest regression coefficient. The highest degree of correlation existed between P. includens adults and subsequent larval populations separated by a 2-week period at every site in 1977. However, during 1978 adult and larval populations separated by 4 weeks exhibited the highest correlation.

Concentration differences of looplure were evaluated for field trapping efficiency and electrophysiological responses with P. includens, T. ni and R. ou. Traps baited with 1000 ug of the lure captured a significantly larger (P<.05) number of male P. includens and T. ni than any other concentration; R. ou males were caught at a greater rate in traps baited with 100 ug, significantly more (P<.05) than with 1000 ug. Electroantennogram (EAG) studies demonstrated that antennae of male P. includens have a lower response threshold to looplure than either T. ni or R. ou antennae, the latter demonstrating the highest significant threshold of response. No differences in the stimulus-response functions of the 3 species were detected.
CHAPTER I

Plusiinae Populations in Louisiana Soybean Ecosystems as Determined with Looplure-baited Traps
Abstract

An adult population survey of 4 species of the noctuid subfamily Plusiinae was conducted in soybean ecosystems of south, south central and north central Louisiana. Sticky-traps baited with synthetic sex pheromone (Z)-7-dodecen-1-ol acetate were used as the sampling tools for 2 growing seasons.

The soybean looper Pseudoplusia includens (Walker) reached the highest densities of the plusiine complex with 4 and 5 generations detected in the southern and central regions of the state. Moth density was greatest at Krotz Springs (south central site) during 1977 and 1978; the lowest levels were detected at Niblett (southern site). Males were collected at the southernmost site on or before the time of initial capture at either of the more northern locations. Initial captures occurred in mid-June (the first sampling period) at all 3 locations during 1977; however, in 1978 adults were initially captured in mid-June at the southern location and in early August at the 2 northern sites. During both years highest levels of capture occurred in September at all sites.

Although Rachiplusia ou (Guenee) were found to contribute considerably to the plusiine population in June, adult densities were quite low during the later summer months. Trichoplusia ni (Hubner) and T. oxygramma (Geyer) seldom attained high numbers at any location.
Introduction

Even before the identification of bombykol (\( (E,Z)-10,12 \)-hexadecadien-1-ol) as the sex pheromone of the silkworm moth, *Bombyx mori*, in 1959 (Butenandt et al 1959), scientists were intrigued by the observed chemical communication between the sexes of insects. The possible utilization of this communication link in both the indirect and direct control of insect pests has become, and certainly will remain, the ultimate goal of many entomologists. Employment of pheromone lures as tools in monitoring moth flights and in assessing population densities has been well-documented (Minks and DeJong 1975, Madsen and Vakenti 1972, Toscano et al 1974). Two population survey studies were conducted in Florida, Georgia and South Carolina by Chalfant et al (1974) and Mitchell et al (1975) using black-light traps baited with (\(Z\)-7-dodecen-1-ol acetate to monitor adult populations of *Trichoplusia ni* (Hubner) and *Pseudoplusia includens* (Walker), respectively. Conclusions concerning the possible northward and southward movement of the 2 species and their seasonal distributions were made based on moths collected in the pheromone traps.

(Z)-7-dodecen-1-ol acetate, or looplure, has been identified as the sex pheromone of 5 noctuid moths and attracts 11 other species in the field (Berger 1966, Berger and Canerday 1968, Shorey et al 1965, Tumlinson et al 1972, Tamaki 1977). The 5 species for which looplure is the apparent sex pheromone include *Autographa biloba* (Stephens), *A. californica* (Speyer), *Rachiplusia ou* (Guenee), along with *P. includens*, the soybean looper, and *T. ni*, the cabbage looper. All are members of the noctuid subfamily *Plusiinae*. 
In an effort to learn more about various aspects of plusiine populations in Louisiana soybean ecosystems, particularly species composition, seasonal distributions and relative abundances, their population dynamics and possible migrations, results are reported for an adult population survey conducted during 2 soybean growing seasons.
Materials and Methods

Moth populations were monitored at 3 experimental sites from mid-June through September during 1977 and from mid-May through September in 1978. Locations were chosen to represent the various soybean ecosystems of the state. Figure 1 shows the location of the trapping sites; each was a privately owned soybean field ranging in size from ca. 80-200 ha. Sites included: 1) Niblett, Jefferson Davis Parish, the southern location (ca. 30°N); 2) Krotz Springs, St. Landry Parish, the south central site (ca. 30°30'N); and 3) Bunkie, Avoyelles Parish, the north central site (ca. 31°N).

Methods of trapping were standardized at each site. Pherocon® 1C (Zoecon Corp.) sticky pheromone traps were used; the traps were hung from aluminum stakes at a height of no greater than 30 cm above the soybean canopy, thereby requiring adjustments throughout the study period. Stakes were placed 15 m apart (a standard similar to that described by Lingren et al 1978). Traps baited with 0.1, 0.5 and 1 mg of the synthetic looplure (Farchan Chemical Co.) were monitored at each site. The acetate sex pheromone was dissolved in hexane and soaked into rubber septa (5 x 9 mm rubber stoppers, sleeve type, Arthur H. Thomas Co.). Traps were baited weekly and replaced biweekly. Treatments were replicated twice and randomized weekly. Moths were collected and brought to the laboratory each week for identification, using the male genitalia characters described by Eichlin (1975).
Fig. 1. Sampling sites of plusiine survey designated S (southern -- Niblett), SC (south central -- Krotz Springs), NC (north central -- Bunkie).
Results

Only 4 of the 11 species of the plusiine moths known to occur in Louisiana (Chapin and Callahan 1967) were captured during the entire survey period. These were P. includens, T. ni, R. ou and T. oxygramma (Geyer). Figures 2-13 show the results of the study. The 0.5 mg concentration of looplure proved to be the most effective for capturing all 4 species (Alford and Hammond, in manuscript); however, population levels are expressed as the mean number of insects per trap per week, regardless of concentration. Results will be presented as separate discussions for each species.

Pseudoplusia includens: Soybean looper populations at Niblett, the southern site, are graphically represented in Fig. 2a and 2b. During 1977, the initial capture was made during the 1st observation period, June 12-18. Peaks of adult populations were evident in early and late July, late August and mid-September. The largest capture rate occurred during the week July 24-30 (ca. 7 moths/trap). The 1st capture of P. includens in 1978 occurred June 18-24. Peak capture rates of approximately 5 males/trap occurred August 20-26 and 17 males/trap during Sept. 24-30.

At Krotz Springs in 1977, as in Niblett, the 1st observation period, June 12-18, was also the 1st positive collection period (Fig. 3a). Small peaks were evident in early and late July and mid-August. Relatively large peaks were monitored Sept. 4-10 and Sept. 18-24 (ca. 12 and 15 males/trap, respectively). During 1978 the 1st collection occurred July 30-Aug. 5 (Fig. 3b). Peaks occurred in moth capture in mid-August and mid-September, and a maximal capture rate of almost 60 moths/trap occurred Oct. 1-7.
Fig. 2a. Mean capture rate of male *P. includens* at Niblett (southern site) during 1977.
Fig. 2b. Mean capture rate of male \textit{P. includens} at Niblett (southern site) during 1978.
Fig. 3a. Mean capture rate of male _P. includens_ at Krotz Springs (south central site) during 1977.
Fig. 3b. Mean capture rate of male *P. includens* at Krotz Springs (south central site) during 1978.
In 1977, with Bunkie serving as the north central location, the initial male soybean looper capture was made during the 1st observation period, June 12-18 (Fig. 4a) as with the 2 more southern sites. Several peaks of adult populations were evident during the season with the largest mean capture rate of ca. 12 moths/trap taking place during the week of Sept. 11-17. The initial capture of *P. includens* males in 1978 occurred July 30-Aug. 5 (Fig. 4b). The largest capture rate for the season took place Sept. 24-30 with over 30 moths/trap caught during the week.

*Trichoplusia ni*: Cabbage looper populations monitored in the study seldom reached high levels. In the Niblett area during 1977 they were captured only during the 1st (June 12-18) and last (Sept. 11-17) weeks (Fig. 5a). As in the previous season, the 1st capture of *T. ni* males occurred in the 1st observation period during 1978 (Fig. 5b), but this was actually 1 month earlier (May 15-21) than in 1977. Males were caught in June and throughout August and September; the largest mean capture rate occurred Sept. 24-30 (ca. 5 males/trap).

Males were collected during the 1st sample period (June 5-11) of 1977 at Krotz Springs (Fig. 6a). There was a late season build-up in the population noted, with the highest mean rate of capture taking place Sept. 11-17 (ca. 6 males/trap). Again, in 1978, the initial capture of a cabbage looper male was made during the 1st week of sampling, May 21-27 (Fig. 6b). Males were collected late in the season at rates of about 4 moths/trap/week.

In the Bunkie area during 1977, cabbage looper males were initially captured during the 1st collection period (June 12-18); they were caught intermittently throughout the season with the largest capture
Fig. 4a. Mean capture rate of male _P. includens_ at Bunkie (north central site) during 1977.
Fig. 4b. Mean capture rate of male *P. includens* at Bunkie (north central site) during 1978.
Fig. 5a. Mean capture rate of male *T. ni* at Niblett (southern site) during 1977.
Fig. 5b. Mean capture rate of male *T. ni* at Niblett (southern site) during 1978.
Fig. 6a. Mean capture rate of male *T. ni* at Krotz Springs (south central site) during 1977.
Fig. 6b. Mean capture rate of male *T. ni* at Krotz Springs (south central site) during 1978.
rate of approximately 5 moths/trap taking place Sept. 4-10 (Fig. 7a). Similar results were evident for Bunkie in 1978 (Fig. 7b), again with the initial capture occurring during the 1st sample period (June 4-10). Adults were collected throughout the season with the main peak of ca. 4 males/trap occurring Sept. 3-9.

*Rachiplusia ou*: Male moth capture was highest during both study years for the 1st observation period in Niblett (Fig. 8a and 8b). Over 18 moths/trap were collected for the period June 12-18 during the 1977 season; a maximal mean capture rate of 2 males/trap was collected in 1978. There were abrupt declines in the population levels after these initial peaks for the 2 seasons. The same trend was noted at Krotz Springs (Fig 9a and 9b) with the greatest adult captures (ca. 12 males/trap in 1977 and 2 males/trap in 1978) occurring in the early season (June to mid-July). *R. ou* were collected at low levels throughout the remainder of the sampling periods. The early seasonal pattern was also evident in the Bunkie area during both years. Over 15 moths/trap were collected June 12-18 during 1977; a maximal rate of capture of ca. 7 moths/trap occurred July 9-15, 1978 (Fig. 10a and 10b).

*Trichoplusia oxygramma*: As was the case with the cabbage looper, relatively few male *T. oxygramma* were captured throughout the course of the study. No clear pattern of seasonal distributions was demonstrated in Niblett (Fig. 11a and 11b). Moths were collected throughout the 2 seasons, with highest levels of fewer than 2 males/trap/week. At Krotz Springs, during both sampling years, few moths were trapped in the early season (Fig 12a and 12b). Fewer than 3 *T. oxygramma*/trap were captured Sept. 4-10, 1977, and fewer than 1 moth/trap was the maximal capture rate during 1978 at the south central location. In Bunkie,
Fig. 7a. Mean capture rate of male *T. ni* at Bunkie (north central site) during 1977.
Fig. 7b. Mean capture rate of male *T. ni* at Bunkie (north central site) during 1978.
Fig. 8a. Mean capture rate of male *R. ou* at Niblett (southern site) during 1977.
Fig. 8b. Mean capture rate of male *R. ou* at Niblett (southern site) during 1978.
Fig. 9a. Mean capture rate of male *R. ou* at Krotz Springs (south central site) during 1977.
Fig. 9b. Mean capture rate of male *R. ou* at Krotz Springs (south central site) during 1978.
Fig. 10a. Mean capture rate of male *R. ou* at Bunkie (north central site) during 1977.
Fig. 10b. Mean capture rate of male *R. ou* at Bunkie (north central site) during 1978.
Fig. 11a. Mean capture rate of male *T. oxygramma* at Niblett (southern site) during 1977.
Fig 11b. Mean capture rate of male *T. oxygramma* at Niblett (southern site) during 1978.
Fig. 12a. Mean capture rate of male *T. oxygramma* at Krotz Springs (south central site) during 1977.
Fig. 12b. Mean capture rate of male *T. oxygramma* at Krotz Springs (south central site) during 1978.
males were captured at low levels (i.e., ca. 1 moth/trap) throughout the sampling periods (Fig. 13a and 13b) of the 2 study years.
Fig. 13a. Mean capture rate of male *T. oxygramma* at Bunkie (north central site) during 1977.
Fig. 13b. Mean capture rate of male *T. oxygramma* at Bunkie (north central site) during 1978.
Discussion

The soybean looper reaches higher densities in Louisiana soybean ecosystems than any other member of the subfamily Plusiinae. Burleigh (1972), while monitoring *P. includens* larval populations at 3 locations in the state comparable to those used in the present study, reported the soybean looper goes through 4 generations/year in Louisiana's soybean fields. He found that the rice ecosystem soybean looper population (southwest La. -- Niblett) was characterized by low levels of infestation, the cleared hardwood forest ecosystem (south central La. -- Krotz Springs) held a median position in larval density, and the cotton ecosystem (north central La. -- Bunkie) was characterized by a dense larval population in August or September. Wuensche (1976) monitored the larval populations in the same areas and reported a greater number of larvae in the Niblett area during 1975; in 1969 he found a higher density in Bunkie. (No cotton was planted in the Bunkie area during 1975, 1977 or 1978).

In the results presented here, 4 and 5 adult generations of *P. includens* were detected in the southern and central regions of the state. Five generations were monitored during 1977, and it should be noted that 1977 will be remembered as one of high noctuid population levels throughout the southeast United States. Early moth appearances and extremely high numbers were quite prevalent throughout Louisiana for many noctuids, the soybean looper being no exception. Adult density was greatest at Krotz Springs during 1977 and 1978; the lowest levels were detected in the southern area (Niblett).

Soybean looper adult males were collected at the southermost site on or before the times of initial capture at any more northern location.
The population peaks occurring at Niblett were substantially less and 1 to 3 weeks earlier than the adult peaks in the other areas during 1978. The population curves for that year were practically indistinguishable for Krotz Springs and Bunkie. Adult populations during 1977 were almost identical temporally at the 3 locations.

The general trend of soybean looper populations in the Louisiana soybean ecosystems may be described as one of initial appearance in the late spring in the southern regions and characterized by a northward, possibly statewide, expansion. High densities are reached throughout the state in late summer and early fall, particularly in central and north Louisiana. During each year of the survey, soybean looper larvae were collected 1 to 3 weeks previous to the initial adult captures in each area of the state (R.M. McPherson, personal communication), but never in the actual study site (i.e., soybean field). Possible categorization of the species into Class I of Johnson's (1969) adaptive dispersal or migration scheme may be fitting. Females emigrating from a breeding site (in this case a more southern site), dispersing, ovipositing and dying may explain the presence of immatures before adult males are captured.

_T. ni_ and _T. oxygramma_ populations in Louisiana soybeans seldom attain levels warranting much attention when considering plusiine moths. Generally, _T. ni_ adults are found in each region at similar densities early in the growing season and again in the latter part. This trend may be due to the greater prevalence for alternate or preferred hosts during the midseason, particularly in the cotton-growing areas of the state (i.e., from Bunkie northward). _T. oxygramma_ adults are seldom
found in the early season but appear primarily in late June or early July. These moths may be captured at low rates throughout the remainder of the growing season.

*R. ou*, on the other hand, may contribute considerably to the Plusiinae population of the soybean ecosystem, especially in the early part of the growing season. Mean capture rates in June often equal or exceed those of *P. includens* captured in August of September in every region. *R. ou* adult densities are quite low during the warmer summer months of July and August, but a gradual reappearance and/or population buildup is evident in the late summer and early fall.
LITERATURE CITED

Alford, A. R., and A. M. Hammond. In manuscript. Sex pheromone concentration as a factor in the reproductive isolation of 3 plusiine moths.


CHAPTER II

Pheromone Trap Capture Rates as Population Indicators of
the Soybean Looper *Pseudoplusia includens* (Walker)
Abstract

Sticky-traps baited with synthetic sex pheromone (Z)-7-dodecen-1-ol acetate, or looplure, were used in the monitoring of *Pseudoplusia includens* (Walker) flights and in assessing population densities. Estimates of adult density levels in 3 Louisiana soybean ecosystems were used to predict subsequent larval population densities for 2 growing seasons. Simple linear regression equations were generated from these data.

Regression coefficients for the 3 sites during 1977 increased with a northward progression, but low correlation coefficients (r) existed between the adult and larval populations for all locations. Substantially higher r values were determined for 1978, but the southern site unexpectedly exhibited the highest regression coefficient value.

The highest degree of correlation in 1977 existed between *P. includens* adult and subsequent larval populations separated by a 2-week period. However, in 1978 adult and larval populations separated by 4 weeks exhibited the highest correlation.
Introduction

Over the last 2 decades, many pheromones and related semiochemicals have been identified and synthesized. Their practical application is still primarily in an exploratory phase, but reports of their successful use in pest control programs are increasing. The potential use of sex pheromones in modern insect pest management can be divided into 2 categories: direct and indirect control. The direct control strategy involves mass-trapping, which may reduce insect populations to acceptable levels or concentrate them within a limited area for insecticide or other treatment, and permeation of the atmosphere with pheromone or antipheromone, which may reduce pest populations by a reduction in the successful mating frequency. Indirect control encompasses the detection of specific insect pests and/or the determination of the population density or movement of the species (Minks 1979).

Direct control methods have so far been erratic in field performances. A successful mass-trapping program was reported in which Egyptian cotton leafworm, Spodoptera littoralis, egg cluster numbers were reduced, resulting in a reduction of the number of chemical treatments required (Teich et al 1979). According to Minks (1979) the mass-trapping strategy must remove the majority (>90%) of the population in order to be successful, and this level of control is seldom, if ever, obtained. Shorey et al (1974) showed that air permeation of cotton fields throughout the season with hexalure produced mating communication disruption which resulted in reduction of boll infestations by Pectinophora gossypiella larvae to levels comparable to those achieved by the use of commercial insecticides. When
considering the efficacy of a direct control approach, the essential
information regarding mating frequency, next generation population
numbers, and crop damage changes are imperative for an effective
evaluation of the program (Minks 1979). Progress in these areas has
been slow.

The earliest and most successful area concerning the application
of semiochemicals is as monitoring devices in pest management. The
impressive results achieved in this area are quite attractive when
viewed from both their general applicability and their prospects and
successes in commercialization. A growing interest in integrated
control measures has stimulated the study and development of simple
and reliable observation methods, and this characteristic, along with
selectivity and easy handling and identification, are potentially
great advantages of monitoring insects with pheromones.

As early as 1896, Forbush and Fernald (1896) attempted to use
traps baited with live virgin female gypsy moths, Lymantria dispar,
for direct control. While their efforts proved unsuccessful, many
males were captured and found to be efficient detectors of moth infes-
tations. One insect pest which has received considerable attention
regarding the use of sex pheromone traps as monitoring devices is the
codling moth, Laspeyresia pomonella, for which a reliable sampling
method is lacking. The sex pheromone trap offers a method of esti-
mating codling moth populations in a situation where routine spraying
for control is common practice. A treatment level of 2 moths/trap
per week has been particularly useful as the threshold for chemical
treatment (Madsen and Davis 1971, Madsen and Vakenti 1972). Due to
the great influence of weather conditions on the time required between
the initiation of moth flight and larval fruit attack, Batiste et al (1973) suggested that sex traps must be operated in individual orchards if they are to be of real value to integrated control of the codling moth. Madsen and Vakenti (1973) later indicated that pheromone traps and visual inspection for infested fruit must be considered in estimating population levels and determining the need for chemical sprays. Warnings have been given that predictions based on correlations relating trap catch to codling moth damage would be difficult to update and correct as the season progresses (Riedl and Croft 1974).

The summerfruit tortrix moth, *Adorophyes orana*, is a major apple pest in The Netherlands, and a model was designed incorporating sex pheromone trap capture and temperature for the determination of chemical control (Minks and DeJong 1975). A correlation between larval dispersal and moth flight was used to precisely time insecticide applications, reducing the conventional 5 to 7 preventive sprays to 3 or 4 more effective sprays. An equally impressive study was reported by Toscano et al (1974) involving the pink bollworm. Fewer insecticide applications were necessary in cotton fields in which treatments were based on male moth capture than fields on an automatic 5-to 7-day spray schedule. No significant differences between the 2 control methods regarding boll infestations and cotton yields were detected when insecticide applications were based on a mean capture rate of 3.5 to 4.0 moths/hexalure-baited trap per night. Miller and McDougall (1973) obtained a high degree of correlation between catches in traps baited with virgin female spruce budworms, *Choristoneura fumiferana*, and population density in the subsequent generation. On the other hand, capture rates of male lesser peachtree borers, *Synanthedon pictipes*,
Materials and Methods

For 2 seasons, May through September, 1977 and 1978, 3 experimental sites were monitored for *P. includens* populations with the use of pheromone-baited sticky-traps. The sites were privately owned soybean fields with areas of ca. 80-200 ha. Sites were chosen in an effort to represent each major soybean producing area of the state. They included: 1) Niblett, Jefferson Davis Parish, the southern site, rice ecosystem (ca. 30°N); 2) Krotz Springs, St. Landry Parish, the central location, cleared hardwood ecosystem (ca. 30°30'N); 3) Bunkie, Avoyelles Parish, the northern site, cotton ecosystem (ca. 31°N) (See Figure 1).

The commercially available synthetic sex pheromone (Farchan Chemical Co.), (Z)-7-dodecen-1-ol acetate, or looplure, was used at a concentration of 1 mg (Alford and Hammond, in manuscript) dissolved in hexane and soaked into rubber septa (5 x 9 mm rubber stoppers, sleeve type, Arhtur H. Thomas Co.). Pherocon® 1C (Zoecon Corp.) sticky pheromone traps were employed and hung from stakes at a height of no greater than 30 cm above the plant foliage, thereby requiring adjustments throughout both seasons. The stakes were placed 15 m apart (as described by Lingren et al 1978) and in a continuous line running east to west to avoid intertrap interference. Four traps were monitored at each site —— 2 containing looplure and 2 blank controls. Adult collections were made and the baited septa were replaced weekly; traps were replaced biweekly. Moths were brought to the laboratory for identification, primarily using male genitalia characters described by Eichlin (1975).
provided inadequate data to confirm 2 peaks of adult eclosion at low population levels. At high population levels, however, captures were very similar to the pupal skin counts (Yonce et al 1977).

This study was designed to investigate the utilization of the sex pheromone of the soybean looper, *Pseudoplusia includens* (Walker), in an indirect control capacity, i.e., in the monitoring of moth flights and in the assessment of population densities in Louisiana soybean ecosystems. The sex pheromone of the soybean looper was identified as (Z)-7-dodecen-1-ol acetate (Tumlinson et al 1972) and has proven to be attractive to males in the laboratory and field (Kaae et al 1972, Mitchell 1973). The soybean looper is an annual immigrant pest of Louisiana soybeans, invading the state in the spring and often reaching economically damaging levels as a defoliating caterpillar in the late summer months. The species seems to fit into Class I of Johnson's (1969) categorization of adaptive dispersal or migration, i.e., adults with a life-span limited to within 1 season, that emigrate from a breeding site, disperse, oviposit, and die. To date, no efforts have been made which employed the sex pheromone as a monitoring device for this insect in the state. The insects' definite time of appearance into an area and its characteristic exponential growth and expansion patterns made *P. includens* a desirable study species. Estimations of adult population levels were determined based on trap captures, and subsequent larval population density models were generated.
Fig. 1. Sampling sites of *P. includens* adult and larval population density designated S (southern — Niblett), SC (south central — Krotz Springs), N (northern — Bunkie).
Larval populations were also sampled weekly at each site after plants reached the V3 stage of development (according to Fehr et al 1971). A standard 38 cm diameter sweep net was used, and 1000 sweeps per site per week were taken in an area not more than 100 meters from the trap line. Larvae were identified using characters described be Eichlin (1975) in the early part of each study period, but after July larvae were identified only as loopers. Increasingly larger numbers of larvae in the late season and the fact that in Louisiana over 90% of all loopers collected in soybeans are *P. includens* (Hensley et al 1964) justified this practice.

The experimental design for this study utilized 2 years, 3 locations, 2 replicates of the pheromone concentration, and an unequal number of sample dates (12-22) per location x year combination. Data were subjected to a general linear model procedure for performing simple linear regression (Barr et al 1976).
Results

Figures 2 and 3 graphically illustrate examples of the populations detected during the study. Figure 2 shows the adult male soybean loopers and larvae collected during the 1977 season at Bunkie, the northern site. The mean number of adults captured per week in the baited traps and the mean number of larvae per 100 sweeps each week are plotted. Figure 3 depicts both adult male and larval populations collected during 1978 at the same site. At every location (within the sampling areas) and during each season larvae were collected 1 to 3 weeks after the initial capture of male moths. Soybean looper adults were captured in mid-June (the initial sample period) in 1977 at all experimental sites, but during 1978 the 1st captures occurred in late June in Niblett and in early August in Krotz Springs and Bunkie. At no time during the course of the study did larval populations reach the treatment threshold recommended by Louisiana State University for this defoliating caterpillar (150 larvae/100 sweeps).

When attempting to compare and correlate the population characteristics of the adults and larvae at a particular site, a time-lag procedure must be implemented. This allows the superimposing of the 2 life stage population curves and thus eases the visual and statistical inspection for similarities in the 2 curves.

Table 1 gives the correlation coefficients (r) and coefficients of determination (r²) for the relationships between the number of adults captured during any given week (X₀) and the number of larvae collected during the same week and for each successive week for a month (X + 1 to X + 4). For each site during 1977 the highest degree
Fig. 2. Mean capture of *P. includens* adult males and larvae at Bunkie, La. (northern site) during 1977.
Fig. 3. Mean capture of _P. includens_ adult males and larvae at Bunkie, La. (northern site) during 1978.
Table 1. Correlation coefficients (r) and coefficients of determination (r²) for adult and larval *P. includens* populations relationships in 3 Louisiana soybean ecosystems.

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>WEEK</th>
<th>1977</th>
<th></th>
<th>1978</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>r</td>
<td>r²</td>
<td>r</td>
<td>r²</td>
</tr>
<tr>
<td>Niblett</td>
<td>Xo</td>
<td>-0.157</td>
<td>0.025</td>
<td>Xo</td>
<td>0.261</td>
</tr>
<tr>
<td></td>
<td>X+1</td>
<td>0.069</td>
<td>0.005</td>
<td>X+1</td>
<td>-0.006</td>
</tr>
<tr>
<td></td>
<td>X+2</td>
<td>0.533</td>
<td>0.284</td>
<td>X+2</td>
<td>0.479</td>
</tr>
<tr>
<td></td>
<td>X+3</td>
<td>0.435</td>
<td>0.189</td>
<td>X+3</td>
<td>0.622</td>
</tr>
<tr>
<td></td>
<td>X+4</td>
<td>-0.074</td>
<td>0.006</td>
<td>X+4</td>
<td>0.873</td>
</tr>
<tr>
<td>Krotz</td>
<td>Xo</td>
<td>-0.049</td>
<td>0.002</td>
<td>Xo</td>
<td>0.757</td>
</tr>
<tr>
<td>Springs</td>
<td>X+1</td>
<td>0.068</td>
<td>0.005</td>
<td>X+1</td>
<td>0.603</td>
</tr>
<tr>
<td></td>
<td>X+2</td>
<td>0.417</td>
<td>0.173</td>
<td>X+2</td>
<td>0.662</td>
</tr>
<tr>
<td></td>
<td>X+3</td>
<td>-0.015</td>
<td>0.001</td>
<td>X+3</td>
<td>0.659</td>
</tr>
<tr>
<td></td>
<td>X+4</td>
<td>0.218</td>
<td>0.046</td>
<td>X+4</td>
<td>0.855</td>
</tr>
<tr>
<td>Bunkie</td>
<td>Xo</td>
<td>-0.039</td>
<td>0.002</td>
<td>Xo</td>
<td>0.838</td>
</tr>
<tr>
<td></td>
<td>X+1</td>
<td>-0.012</td>
<td>0.001</td>
<td>X+1</td>
<td>0.974</td>
</tr>
<tr>
<td></td>
<td>X+2</td>
<td>0.591</td>
<td>0.349</td>
<td>X+2</td>
<td>-0.035</td>
</tr>
<tr>
<td></td>
<td>X+3</td>
<td>0.430</td>
<td>0.185</td>
<td>X+3</td>
<td>0.109</td>
</tr>
<tr>
<td></td>
<td>X+4</td>
<td>-0.091</td>
<td>0.009</td>
<td>X+4</td>
<td>0.943</td>
</tr>
</tbody>
</table>

*P<.05

**P<.01
of correlation existed for the X + 2, or a 2-week lag, analysis. Therefore, for that year, the synchronization was exhibited between P. includens adult and larval populations separated by a 2-week period. During 1978 the highest correlation coefficient occurred for the 4-week lag (X + 4) between adults and larvae at Niblett and Krotz Springs. There is only a slight difference in the r values of X + 1 and X + 4 in Bunkie. Adult population characteristics were followed by similar patterns in the larval populations 4 weeks later in 1978. The r and r² values of 1978 are substantially greater and the levels of significance much lower than the corresponding values of 1977.

Linear regression equations were generated from the data for each site and year using the lag period which provided the best correlation between adult and larval population curves for the year as a whole (i.e., 2 weeks for 1977 and 4 weeks for 1978). Table 2 gives the appropriate equations. The functional relationships between adults and larvae are indicated by the general equation Y = a + bX, where

Y = the dependent variable (number of larvae/1000 sweeps at week "X"),

X = the independent variable (number of adults/trap "X+" weeks previous),

a = the Y-intercept (number of larvae/1000 sweeps when no adults captured "X+" weeks previous), and

b = regression coefficient (the functional dependence of Y on X).
Table 2. Linear regression equations for 1977 and 1978 adult and larval *P. includens* populations relationships.

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>1977 (2-week lag)</th>
<th>1978 (4-week lag)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Niblett</td>
<td>( Y = 8.08 + 1.157 ) (X)</td>
<td>( Y = 8.39 + 51.085 ) (X)</td>
</tr>
<tr>
<td>Krotz Springs</td>
<td>( Y = 6.67 + 4.914 ) (X)</td>
<td>( Y = 12.87 + 14.515 ) (X)</td>
</tr>
<tr>
<td>Bunkie</td>
<td>( Y = 6.16 + 6.123 ) (X)</td>
<td>( Y = 5.18 + 32.238 ) (X)</td>
</tr>
</tbody>
</table>
Discussion

The primary goal in insect pheromone research is to use the data acquired in a well designed study for the development of a control technique that is specific for the pest species as well as being harmless to the environment (Roelofs 1978). Reported here are the results of a preliminary study of the feasibility of using the sex pheromone of *P. includens* as an indirect control tool in the monitoring of moth flight and in the assessment of population density, specifically the economically important larval stage.

During 1977 and 1978 looper larvae were collected previous to the initial adult capture in some areas of the state, but never in the actual sampling area. (They were collected in adjacent fields in Bunkie previous to initial adult collection, R.M. McPherson, personal communication.) Also, it should be noted that 1977 will be remembered in the southeast United States as a year of early appearances and high densities of noctuid species, and the soybean looper populations in Louisiana were no exception. But, the densities encountered during 1977 in the study areas were much lower than those in 1978, evidenced by lower adult capture rates and larval collection rates at each site. The variation from year to year at the same location was evidenced from the results, and possible contributing factors should be mentioned. Soybeans were drill-planted in 1977 and row-planted in 1978 in Niblett, resulting in an increase in the sampling efficiency of the sweep net procedure during the latter year. Secondly, the plant varieties and the planting dates and subsequent growth stages varied between sites and years due to the direct influence of weather on the cultural
practices of the farmers. Finally, the parasitism, fungal and viral infection rates often vary drastically among years and locations. These factors certainly exert consequences on all life stages of an insect species, and these reasons, along with others, may explain the variability in the relationships between adult and larval populations across sites and years. The overall low $r^2$ values during 1977, and the consequential low levels of significance, may be reflective of the extraneous factors mentioned.

However, the relationships of the regression coefficients ($b = 1:5:6$, Niblett:Krotz Springs:Bunkie) during 1977 were expected. Burleigh (1972), while monitoring locations in Louisiana almost identical to those of the present study, found maximal soybean looper populations of 3.5 larvae/100 sweeps in the southern area, 28 larvae/100 sweeps in the central area, and 187 larvae/100 sweeps in the northern area. This corresponds to an approximate 1:8:53 ratio of the larval populations at the 3 sites, increasing as one moves northward. Adult food, i.e., a nectar source such as cotton, could be the key to the differences in populations of the pest in the different agricultural ecosystems (Jensen et al 1974). Cotton is more available in the Bunkie area than the other areas, and the soybean looper is a serious pest in this area of the state and northward. Also to be considered is the fact that parasitism in the southern region is much higher (Burleigh 1972), particularly in the early portion of the growing season, which partially accounts for the corresponding relationships.

The relatively high larval densities recorded at Niblett in 1978, reflected by a $> 51$ regression coefficient, is puzzling. Other than the factors mentioned previously (i.e., sampling efficiency, rates of
parasitism, etc.) consideration must be made of the 6-week earlier detection of adult *P. includens* at Niblett than the 2 more northern sites. The 38 Larvae/100 sweeps maximal density reported is over 10 times the maximal density reported by Burleight at Lacassine (located ca. 10 km NNW from the Niblett study area). However, Wuensche (1976) monitored soybean looper larval populations in the same areas and reported a greater number of larvae in the Niblett/Lacassine area than Krotz Springs or Bunkie during 1975. In 1969 he found a higher larval density in Bunkie. (No cotton was planted in the Bunkie area during 1975, 1977 and 1978). The regression coefficients of 1978 for Krotz Springs and Bunkie (14.5 and 32.2, respectively) are noticeably higher than those of the previous year, but their relationships, with respect to latitude, were not unexpected.

In the construction of a predictive model using adult capture rates of a pheromone trap to predict next generation population densities, there are numerous weaknesses. Minks (1979) stated that pheromone traps cannot reliably determine the threshold population levels of insect pests, which are essential to know for a correct application of supervised or integrated control measures. For a correct evaluation of pheromone trapping as a sampling method, comparison is necessary with other, preferably absolute, sampling methods such as direct counting of eggs, larvae, etc. Roelofs (1978), along with Minks and DeJong (1975), maintained that the system could be quite valuable if thermal units are included; Madsen and Vakenti (1972) and Batiste et al (1973) suggested that entire weather parameters should be incorporated; and the trap and pheromone efficiencies are important qualities of a precise sampling method (Minks 1979). The "competition effect"
between native females and the attractant-baited traps apparently alters the linear relationship between the capture rate and the actual male population density of several moth species (Carde' 1979).

The value of pheromone traps as tools for monitoring moth flights remains questionable. The capture of male soybean looper moths before the initial collection of larvae in the sampling area is indeed a positive quality, but the erratic correlations between adult and larval population curves render the method, at best, ineffective as a dependable means of assessing population density.

In order to attain a level of highly effective sampling, consideration must be made of other influencing factors such as parasitism and disease effects, weather (particularly temperature) influences, locality properties (including the variation in temporal appearances of the species), alternate host availability and preferences, and the biological factors of the species such as its flight range, natural fecundity and mortality, and behavior. Finally, as Minks (1979) pointed out, constant support and attention is an absolute necessity to the even simple and successfully operating forecasting systems of threshold levels based on pheromone trap catches.
LITERATURE CITED

Alford, A. R., and A. M. Hammond. In manuscript. Sex pheromone concentration as a factor in the reproductive isolation of 3 plusiine moths.


Teich, I., S. Neumark, M. Jacobson, J. Klug, A. Shane, and R. M. Waters. 1979. Mass trapping of males of Egyptian cotton leafworm (Spodoptera littoralis) and large-scale synthesis of Prodlure. In: Chemical Ecology: Odour Communication in


CHAPTER III

Field and Laboratory Concentration Evaluation

of 3 Plusiine Species to Looplure
Abstract

Concentration differences of (Z)-7-dodecen-1-ol, or looplure, were evaluated for field trapping efficiency and electrophysiological responses with male *Pseudoplusia includens* (Walker), *Trichoplusia ni* (Hubner) and *Rachiplusia ou* (Guenee). Sticky-traps baited with 1000 μg of the lure captured a significantly greater (P<.05) number of male *P. includens* and *T. ni* than any other concentration; *R. ou* males were caught at a greater rate in traps baited with 100 μg of looplure, significantly more (P<.05) than with 1000 μg.

Electroantennogram (EAG) studies demonstrated that antennae of male *P. includens* have a lower response threshold to looplure than either *T. ni* of *R. ou* antennae, the latter demonstrating the highest significant threshold of response. No differences in the stimulus-response functions of the 3 species were detected.
Introduction

Pheromones have been shown to be involved in the mediation of numerous behavioral responses, with some of the more common types being trail marking and following, alarm and dispersal, territoriality, synchronization, aggregation and sexual communication, the latter being of concern presently. Sex pheromones are released into the environment by 1 sex and stimulate reactions in the opposite sex that either directly or indirectly enhance the likelihood that mating will occur (Shorey 1976). Especially among insects, this pheromone communication system of bringing 2 sexes together for mating purposes appears to be indispensable. Pest species which are obviously highly dependent on pheromonal communication for their survival have attracted the attention of scientists interested in the manipulation of the pest's behavior to practical advantage. Early observations of the chemical communication between the 2 sexes in insects were made more than a century ago, the most noted being J. Henri Fabre's tests with silkworm moth males' attraction to caged females. The first actual chemical identification of a pheromone was in 1959 (Butenandt et al 1959). These investigators identified (E)-10, (Z)-12-hexadecadien-1-ol as the sex pheromone of the female silkworm moth, Bombyx mori. The 2nd identification was that of the female cabbage looper moth, Trichoplusia ni (Hubner) by Berger (1966). He found (Z)-7-dodecen-1-ol acetate to be the monocomponent pheromonal system in the premating behavior of the moths.

(Z)-7-dodecen-1-ol acetate, or looplure, is of particular interest because this 1 chemical has been identified as the sex pheromone for 5 noctuid moths (Berger and Canerday 1968, Shorey et al
1965, Tumlinson et al 1972) and attracts 11 other species in the field (Tamaki 1977). The 5 noctuids for which looplure is the apparent sex pheromone include Autographa biloba (Stephens), A. californica (Speyer), Pseudoplusia includens (Walker), Rachiplusia ou (Guenee) and T. ni, all members of the subfamily Plusiinae.

The lack of apparent specificity in the sex pheromones of this group has intrigued researchers for over a decade. Shorey et al (1965) and Berger and Canerday (1968) demonstrated that not all species of Plusiinae tested exhibit the characteristic sex attractant responses to looplure, but all responded to extracts of all other species. If these different species utilize this single chemical as their sex pheromone, other factors must be involved in the reproductive isolation of each species. These may be differences in geographic distribution, habitat preferences, seasonal or daily cycles and rhythms, morphological differences, male and female behavioral interactions and pheromone release rates or concentration differences. The possibilities of the presence of secondary chemicals, and consequently multicomponent sex pheromonal systems, are not without merit.

Pheromone concentration has been demonstrated to be an important reproductive isolating mechanism within this group. The 2 plusiines T. ni and A. californica overlap widely in their geographic distribution, seasonal cycles and daily mating rhythms; but T. ni males are more attractive to release rates of looplure 10 to 100 times greater than the most attractive release rates for A. californica males (Kaae et al 1973).

If members of the plusiine group do utilize a monocomponent sex pheromone system, which is questionable based on a hypothesis
and results reported by Roelofs (1978a) and Bjostad et al (1979), variable release rates of the single chemical among species could be an important mechanism of reproductive isolation. The 3 species studied presently do overlap in their geographic distributions, habitat preferences and seasonal and daily cycles (Alford and Hammond, in manuscript). The effects of several concentrations of looplure were evaluated for field attractancy efficiency for *P. includens*, *T. ni* and *R. ou*, and the male antennal receptiveness of the 3 species to the chemical was examined using the electroantennogram technique in an effort to relate the electrophysiological responses to the moths' behavior.
Materials and Methods

Field Trapping Tests: From June through September, 1976-78, 4 experimental sites were used in an effort to span the entire state of Louisiana. The sites were privately owned soybean fields ranging in size from 80-200 ha. Sites included: 1) Niblett, Jefferson Davis Parish, located at latitude ca. 30°N; 2) Krotz Springs, St. Landry Parish, (ca. 30°30'N); 3) Bunkie, Avoyelles Parish, (ca. 31°N); and 4) Bonita, Morehouse Parish (ca. 33°N). A site near Angola, La. was used during 1976 instead of the Bunkie site, but due to its isolation, the more accessible Bunkie location was chosen for 1977 and 1978. Also, the Bonita site was sampled during 1977 and 1978 only. (Fig. 1)

Populations of the 3 plusiine species were monitored at each of the experimental sites with the use of a commercially available synthetic sex pheromone (Farchan Chemical Co.). Varying concentrations of looplure were dissolved in hexane and soaked into rubber septa (5 x 7 mm rubber stoppers, sleeve type, Arthur H. Thomas Co.). Pherocon® 1C (Zoecon Corp.) sticky-traps were chosen at the onset, and no alterations were made during the course of the study. The traps were hung from aluminum stakes at a height of no more than 30 cm above the plant canopy, thus requiring adjustments throughout each growing season. The stakes were placed 15 m apart (as described by Lingren et al 1978) and in a continuous line running east to west to lessen interference between concentrations. Two replicates were used at each site.

Experimental concentrations of 100, 500 and 1000 μg were established during the 1st few weeks of the 1976 season. During 1978
Fig. 1. Sampling sites included in field trapping evaluation of sex pheromone concentrations designated S (southern -- Niblett), SC (south central -- Krotz Springs), C (central -- Bunkie) and N (northern -- Bonita).
a 4th concentration of 10 μg was also evaluated in an effort to find a lower concentration in which no male moths were captured. A control trap (i.e., one without the chemical) was included at each site for each replicate.

Adult collections were made and the looplure-baited septa were replaced weekly; the traps were replaced every 2 weeks, and concentrations were randomized weekly. The moths were brought back to the laboratory for identification. In identifying adult plusiines, wing markings are quite variable within species and are subject to loss of character when exposed to harsh weather conditions. For this reason male genitalia were used to assure correct identification using the characters described by Eichlin (1975). Each specimen was dissected using the technique described by Dr. Joan B. Chapin (personal communication), and processes on the valve were used as the primary diagnostic characters. Scanning electron micrographs (Appendix Figures 1-3) show these characters used in the identification process for each species.

The statistical analyses were based on a model containing the following sources of variation: weeks, years, sites and concentrations. There were 3 years, an unequal number of sample dates (weeks) each year (12-22), 3 (or 4) sites, 3 (or 4) concentrations and 2 concentration replicates. An analysis of variance, with the model: year, week/year, site, concentration and site x concentration, was used for the analysis of each species (Barr et al 1976). For the analyses 1 basic assumption was made: the sampling efficiency of the sex pheromone system described was absolute. Therefore, if no male moths of a particular species were captured during a sampling period,
those zero responses were not included in the analysis. Capture rates of the blank (control) traps were not included in the analyses, but capture rates of the pheromone-baited traps were corrected for control capture. (See Table 1 for the model sources of variation and sample sizes associated with each.)

**Electroantennogram (EAG):** Electroantennogram responses of male _T. ni_, _P. includens_ and _R. ou_ to test concentrations were conducted using a modification of the apparatus and procedure described by Roelofs et al (1971). (Freshly excised antennae attached to head capsules were depressed into a wet wax block in a Syracuse watch glass containing insect Ringer's solution. Antennae were exposed to short puffs of air (1 cm³) directed into an airstream of ca. 250 ml/sec. Silver-silver chloride reference and recording electrodes were used. Antennal responses were amplified by a Grass® P 18 Microelectrode D.C. amplifier and displayed on a cathode-ray oscilloscope and chart recorder.) Moths used for the study were reared on an artificial diet (Burton 1969) in the laboratory and maintained at a 14:10 light:dark cycle (_R. ou_ were kept at a 12:12 L:D cycle). Specimens utilized ranged in age from 2-7 days posteclosion, with no particular emphasis placed on exact age or conditioning (i.e., time of exposure in relation to light:dark cycle). Moths of each species were exposed to varying concentrations of the synthetic sex pheromone looplure purchased from Farchan Chemical Co. and verified for purity (>98%). The concentration series were produced by pipetting the appropriate amounts, dissolved in hexane, onto 2 x 5 cm fluted filter paper slips and inserted into disposable glass pipettes for release. Control filter papers were loaded with 5 μl hexane.
Table 1. Sites monitored and number of concentrations evaluated for 3 soybean growing seasons in Louisiana.

<table>
<thead>
<tr>
<th>SITE</th>
<th>1976</th>
<th>1977</th>
<th>1978</th>
</tr>
</thead>
<tbody>
<tr>
<td>Niblett</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Krotz Springs</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Bunkie</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Bonita</td>
<td>0</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
Each antenna was exposed to the same concentrations unless activity and response decreased to a level less than ca. 75% of the initial standard response. All pheromonal stimulations were followed by a 1 minute interstimulus period of clean air exposure. Each test began with the antenna being exposed to a "standard" 1 ug stimulus followed by a control. A 1 ug standard dose was chosen because it elicited a significant EAG response in preliminary studies. Each antenna was then exposed to an ascending series of pheromonal concentrations of 0.00001, 0.00005, 0.0001, 0.0005, 0.001, 0.005, 0.01, 0.05, 0.1, 0.5, 1, 10, 100 and 1000 ug, 2-3 times per concentration. Control and standard exposures were interspersed 3 times within the series and at the end. One antenna was exposed to no more than 1 series.

The evaluation of EAG responses utilized the maximal amplitude elicited by a given stimulus minus the mean response of the preceding and succeeding controls. This "correction" was used to discount possible hexane chemoreception, mechanoreception and mechanical disturbances in the air flow. Payne et al (1970) defined a "significant" mean EAG response as one having an amplitude greater than 3 times the mean standard error of the control above the mean response of the control; their interpretation was employed in this study. The sensitivity of the male antenna to concentrations was recorded as percentage values of the preceding and succeeding standard mean response. Thresholds of response, set by the criterion of Payne et al (1970), were determined on an individual specimen basis. The assumption was made that an individual's threshold is unique due to both intrinsic and extrinsic factors which were not controlled or moderated.
Mean thresholds of response and dosage-response curves were determined for the 3 species.
Results and Discussion

The mean capture rates of the 3 species at the 4 concentrations are presented in Table 2. Significantly greater (P<.05) numbers of male *P. includens* and *T. ni* were captured in traps baited with 1000 μg of looplure than any other concentration. However, the greatest numbers of *R. ou* were caught in traps containing 100 μg of the pheromone, significantly more (P<.05) than with 1000 μg. (See Appendix Tables 1-3 for the analysis of variance procedures for the 3 species.)

The average of the individual thresholds of response for each species determined with the EAG technique are given in Table 3. (See Appendix Tables 4-6 for individual thresholds.) *P. includens* males were determined to have a lower response threshold to the synthetic sex pheromone (0.12 ng) and a slightly higher mean response to the standard 1 μg dosage (2.12 mV). *T. ni* males demonstrated both an intermediate threshold (0.30 ng) and mean standard response (2.09 mV); and male *R. ou* had the highest significant EAG threshold (0.45 ng) and the lowest mean response to the standard (1.59 mV).

Dosage-response curves are presented in Figures 2-4. EAG response is expressed as the mean percentage of the 1 μg standard dose and plotted against the logarithmic concentration of the stimulus. Slopes were obtained from measurements made in mid-range (10^-2 to 10^1) of each stimulus-response curve.

Comparisons of the results obtained by the two methods of concentration evaluation (field trapping vs EAG) reveal that *P. includens* males are captured at highest rates in pheromone traps baited with the highest tested concentration of the synthetic material, and they
Table 2. Mean capture rates of 3 plusiine species at 4 concentrations of synthetic sex pheromone in Louisiana soybean ecosystems.

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>1000 ug</th>
<th>500 ug</th>
<th>100 ug</th>
<th>10 ug</th>
</tr>
</thead>
<tbody>
<tr>
<td>P. includens</td>
<td>6.16 a</td>
<td>4.06 b</td>
<td>1.63 c</td>
<td>0.27 c</td>
</tr>
<tr>
<td>T. ni</td>
<td>1.64 a</td>
<td>0.92 b</td>
<td>0.49 bc</td>
<td>0     c</td>
</tr>
<tr>
<td>R. ou</td>
<td>1.15 a</td>
<td>1.59 b</td>
<td>1.78 b</td>
<td>0.94 a</td>
</tr>
</tbody>
</table>

1 Means followed by same letter in same row are not significantly different at the 5% significance level (Duncan's Multiple Range Test).
Table 3. Calculated thresholds of response to synthetic sex pheromone and mean response to standard dosage (1 μg) of 3 plusiine species.

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>THRESHOLD OF RESPONSE -- ng (± std. error)</th>
<th>RANGE (ng) (Min - Max)</th>
<th>MEAN RESPONSE TO STD -- mV (± std. error)</th>
<th>RANGE (mV) (Min - Max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P. includens</td>
<td>0.12 ± 0.02</td>
<td>0.06 - 0.30</td>
<td>2.12 ± 0.21</td>
<td>0.90 - 3.78</td>
</tr>
<tr>
<td>T. ni</td>
<td>0.30 ± 0.05</td>
<td>0.08 - 0.63</td>
<td>2.09 ± 0.12</td>
<td>1.26 - 2.84</td>
</tr>
<tr>
<td>R. ou</td>
<td>0.45 ± 0.07</td>
<td>0.22 - 0.98</td>
<td>1.59 ± 0.12</td>
<td>0.66 - 3.10</td>
</tr>
</tbody>
</table>
Fig. 2. EAG amplitude vs log concentration of looplure for male $P. \textit{includens}$ (eye-fitted curve).
Fig. 3. EAG amplitude vs log concentration of looplure for male T. ni (eye-fitted curve).
Mean % EAG to STD. Dose

Fig. 4. EAG amplitude vs log concentration of looplure for male R. ou (eye-fitted curve).

slope = 16.8
exhibit a relatively low response threshold to looplure. On the other hand, R. ou males are captured more effectively in traps containing 10-fold less looplure and exhibit a considerably higher threshold of response. Response ranges and slopes of the dosage-response curves are similar for the 3 species, and visual inspection of the curves shows that the general curve characteristics are very similar.

Significant EAG response thresholds and stimulus-response functions for a moth may not be critical to its behavior. Mayer (1973) found the EAG to be much less sensitive than the behavioral assay; his calculated threshold for the EAG of T. ni males (0.33 ng) was over $10^4$ greater than that calculated for attractancy. (Light and Birch 1979 and Payne et al. 1970 found T. ni EAG thresholds of 0.012 ug and 1.5 ug, respectively. Comparisons of these values are not valid due to gross differences in methodology between the studies.) The EAG technique may be most useful in the detection of pheromonal components involved in the natural system (Roelofs 1978b) and not for behavioral analogies.

Conversely, the use of trap capture rates for behavioral analogies may be equally invalid. Carde' (1979) points out that pheromone trap capture with a synthetic chemical often has little biological validity. Important to consider are the limitations of the trap itself on the numbers of insects caught. Population density, site, behavior, trap density and design, as well as pheromone concentration influence capture rates (Minks 1977).

The differences demonstrated between the 3 plusiine species in the field capture study were not evident in the electrophysiological tests. Optimal field attractancy concentrations of looplure were not reflected in the EAG response thresholds, ranges of response, and the
stimulus-response functions. Hopefully, the differences and similarities revealed here in the perception of looplure by the 3 species will prove more valuable when their natural sexual communication systems are more fully understood.
LITERATURE CITED


## Appendix Table 1. Analysis of variance procedure for adult male *P. includens* populations collected in soybean ecosystems in 4 regions of Louisiana during 1976-78 growing seasons.

<table>
<thead>
<tr>
<th>SOURCES OF VARIATION</th>
<th>DEGREES OF FREEDOM</th>
<th>SUMS OF SQUARES</th>
<th>MEAN SQUARES</th>
<th>F VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>2</td>
<td>1455.964</td>
<td>727.982</td>
<td>20.10**</td>
</tr>
<tr>
<td>Week/Year</td>
<td>34</td>
<td>14732.139</td>
<td>433.298</td>
<td>11.97**</td>
</tr>
<tr>
<td>Site</td>
<td>3</td>
<td>429.661</td>
<td>143.220</td>
<td>3.95**</td>
</tr>
<tr>
<td>Concentration</td>
<td>3</td>
<td>2827.266</td>
<td>942.422</td>
<td>26.02**</td>
</tr>
<tr>
<td>Site X Conc.</td>
<td>9</td>
<td>341.115</td>
<td>37.902</td>
<td>1.05</td>
</tr>
<tr>
<td>Error</td>
<td>486</td>
<td>17599.717</td>
<td>36.213</td>
<td></td>
</tr>
</tbody>
</table>

**P < .01**
Appendix Table 2. Analysis of variance procedure for adult male *T. ni* populations collected in soybean ecosystems in 4 regions of Louisiana during 1976-78 growing seasons.
Appendix Table 3. Analysis of variance procedure for adult male *R. ou* populations collected in soybean ecosystems in 4 regions of Louisiana during 1976-78 growing seasons.

<table>
<thead>
<tr>
<th>SOURCES OF VARIATION</th>
<th>DEGREES OF FREEDOM</th>
<th>SUMS OF SQUARES</th>
<th>MEAN SQUARES</th>
<th>F VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>2</td>
<td>88.465</td>
<td>44.233</td>
<td>13.73**</td>
</tr>
<tr>
<td>Week/Year</td>
<td>38</td>
<td>2348.558</td>
<td>61.804</td>
<td>19.18**</td>
</tr>
<tr>
<td>Site</td>
<td>3</td>
<td>124.769</td>
<td>41.590</td>
<td>12.91**</td>
</tr>
<tr>
<td>Concentration</td>
<td>3</td>
<td>46.690</td>
<td>15.563</td>
<td>4.83**</td>
</tr>
<tr>
<td>Site X Conc.</td>
<td>9</td>
<td>14.723</td>
<td>1.636</td>
<td>0.51</td>
</tr>
<tr>
<td>Error</td>
<td>460</td>
<td>4005.138</td>
<td>3.222</td>
<td></td>
</tr>
</tbody>
</table>

**P < .01
<table>
<thead>
<tr>
<th>INDIVIDUAL</th>
<th>THRESHOLD (ng)</th>
<th>MEAN RESPONSE (mV) (std. minus con.)</th>
<th>RANGE (mV) (Min - Max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.09</td>
<td>1.42</td>
<td>1.28 - 1.60</td>
</tr>
<tr>
<td>2</td>
<td>0.13</td>
<td>2.29</td>
<td>1.66 - 2.68</td>
</tr>
<tr>
<td>3</td>
<td>0.08</td>
<td>2.19</td>
<td>1.90 - 2.38</td>
</tr>
<tr>
<td>4</td>
<td>0.14</td>
<td>2.59</td>
<td>2.40 - 2.76</td>
</tr>
<tr>
<td>5</td>
<td>0.09</td>
<td>1.10</td>
<td>0.90 - 1.28</td>
</tr>
<tr>
<td>6</td>
<td>0.11</td>
<td>3.33</td>
<td>3.04 - 3.78</td>
</tr>
<tr>
<td>7</td>
<td>0.09</td>
<td>2.21</td>
<td>2.16 - 2.26</td>
</tr>
<tr>
<td>8</td>
<td>0.06</td>
<td>2.13</td>
<td>1.88 - 2.34</td>
</tr>
<tr>
<td>9</td>
<td>0.30</td>
<td>3.00</td>
<td>2.56 - 3.24</td>
</tr>
<tr>
<td>10</td>
<td>0.14</td>
<td>1.64</td>
<td>1.44 - 1.74</td>
</tr>
<tr>
<td>11</td>
<td>n.c.</td>
<td>1.36</td>
<td>1.30 - 1.40</td>
</tr>
</tbody>
</table>

n.c. -- did not calculate threshold

Appendix Table 4. Results of EAGs of individual *P. includens* males and calculated thresholds of response (std. = 1 ug; con. = 5 ul hexane).
<table>
<thead>
<tr>
<th>INDIVIDUAL</th>
<th>THRESHOLD (ng)</th>
<th>MEAN RESPONSE (mV) (std. minus con.)</th>
<th>RANGE (mV) (Min - Max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.43</td>
<td>1.76</td>
<td>1.58 - 1.98</td>
</tr>
<tr>
<td>2</td>
<td>0.24</td>
<td>2.16</td>
<td>1.84 - 2.24</td>
</tr>
<tr>
<td>3</td>
<td>0.09</td>
<td>1.71</td>
<td>1.58 - 1.78</td>
</tr>
<tr>
<td>4</td>
<td>0.35</td>
<td>2.34</td>
<td>2.21 - 2.60</td>
</tr>
<tr>
<td>5</td>
<td>0.24</td>
<td>2.12</td>
<td>1.84 - 2.44</td>
</tr>
<tr>
<td>6</td>
<td>0.30</td>
<td>2.02</td>
<td>1.75 - 2.25</td>
</tr>
<tr>
<td>7</td>
<td>0.08</td>
<td>1.43</td>
<td>1.26 - 1.56</td>
</tr>
<tr>
<td>8</td>
<td>0.25</td>
<td>1.87</td>
<td>1.61 - 2.21</td>
</tr>
<tr>
<td>9</td>
<td>0.36</td>
<td>2.72</td>
<td>2.54 - 2.84</td>
</tr>
<tr>
<td>10</td>
<td>0.27</td>
<td>2.45</td>
<td>2.21 - 2.60</td>
</tr>
<tr>
<td>11</td>
<td>0.63</td>
<td>2.45</td>
<td>2.12 - 2.80</td>
</tr>
</tbody>
</table>

Appendix Table 5. Results of EAGs of individual T. ni males and calculated thresholds of response (std. = 1 ug; con. = 5 ul hexane).
<table>
<thead>
<tr>
<th>INDIVIDUAL</th>
<th>THRESHOLD (ng)</th>
<th>MEAN RESPONSE (mV) (std. minus con.)</th>
<th>RANGE (mV) (Min - Max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.28</td>
<td>1.32</td>
<td>1.20 - 1.46</td>
</tr>
<tr>
<td>2</td>
<td>0.22</td>
<td>2.20</td>
<td>1.68 - 3.10</td>
</tr>
<tr>
<td>3</td>
<td>0.29</td>
<td>1.45</td>
<td>1.20 - 1.78</td>
</tr>
<tr>
<td>4</td>
<td>0.35</td>
<td>1.78</td>
<td>1.44 - 2.06</td>
</tr>
<tr>
<td>5</td>
<td>0.52</td>
<td>1.75</td>
<td>1.48 - 1.88</td>
</tr>
<tr>
<td>6</td>
<td>0.98</td>
<td>1.40</td>
<td>1.26 - 1.45</td>
</tr>
<tr>
<td>7</td>
<td>0.54</td>
<td>1.72</td>
<td>1.58 - 1.94</td>
</tr>
<tr>
<td>8</td>
<td>0.33</td>
<td>1.56</td>
<td>1.44 - 1.70</td>
</tr>
<tr>
<td>9</td>
<td>0.36</td>
<td>2.14</td>
<td>2.10 - 2.28</td>
</tr>
<tr>
<td>10</td>
<td>0.62</td>
<td>2.27</td>
<td>2.08 - 2.50</td>
</tr>
<tr>
<td>11</td>
<td>n.c.</td>
<td>1.02</td>
<td>0.90 - 1.24</td>
</tr>
<tr>
<td>12</td>
<td>n.c.</td>
<td>1.05</td>
<td>0.66 - 1.36</td>
</tr>
<tr>
<td>13</td>
<td>n.c.</td>
<td>1.07</td>
<td>0.93 - 1.13</td>
</tr>
</tbody>
</table>

n.c. — did not calculate threshold

Appendix Table 6. Results of EAGs of individual *R. ou* males and calculated thresholds of response (std. = 1 ug; con. = 5 ul hexane).
Appendix Figure 1. *P. includens*. Mesal view. Valve of male genitalia. SEM

*Bar* = 500 *um*
Appendix Figure 2. *T. ni*. Mesal view. Valve of male genitalia.

SEM

Bar = 500 μm
Appendix Figure 3. R. ou. Mesal view. Valve of male genitalia.

SEM

Bar = 500 um
VITA

Arthur Randall Alford was born to Hilda and Travis Alford in Baton Rouge, Louisiana on October 31, 1953. He attended public schools in Baton Rouge and Denham Springs, Louisiana and was graduated from Denham Springs High School in 1971. He attended University of Southern Mississippi in Hattiesburg, Mississippi where he received a Bachelor of Science degree in Biology in August, 1974. In August of that year he entered the graduate school of Louisiana State University and received a Master of Science degree in Entomology in May 1976 under the direction of Dr. Edward C. Burns.

On October 28, 1978, he married Susan Smith Tomlin, and he is presently a candidate for the degree of Doctor of Philosophy in Entomology.
EXAMINATION AND THESIS REPORT

Candidate: Arthur Randall Alford

Major Field: Entomology

Title of Thesis: Seasonal Distributions, Relative Abundances and Sexual Communication of the Plusiinae (Lepidoptera: Noctuidae) of Louisiana Soybean Ecosystems.

Approved:

[Signatures]

Date of Examination: May 2, 1980