Seasonal patterns of capture of *Helicoverpa zea* (Boddie) and *Heliothis phloxiphaga* (Grote and Robinson) (Lepidoptera: Noctuidae) in pheromone traps in Washington State.

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ABSTRACT

In each of the 6 years of this study in south central Washington state, male corn earworm moths, *Helicoverpa zea* (Boddie), first appeared in pheromone traps in late May to mid June, and thereafter were present nearly continuously until mid to late October. Maximum numbers of male corn earworm moths captured in pheromone traps occurred in August and early September. Male *Heliothis phloxiphaga* (Grote and Robinson) moths first appeared in traps baited with corn earworm pheromone and conspecific pheromone in April, and were generally present throughout the season until mid to late September. In some years, two peaks of trap capture of *H. phloxiphaga* males was suggestive of two generations per season, with one flight in April and May and the other in July and August. Although both species were caught primarily in traps baited with their appropriate conspecific pheromone, smaller numbers of both species were captured in traps baited with the heterospecific pheromone. *Heliothis phloxiphaga* captured in corn earworm pheromone traps can be misidentified as corn earworm, resulting in false positives for corn earworm in commercial sweet corn or overestimates of corn earworm populations.

Key Words: Seasonal phenology, *Helicoverpa zea*, *Heliothis phloxiphaga*, corn earworm, trapping, pheromone

INTRODUCTION

Helicoverpa zea (Boddie), the corn earworm (CEW), is a pest of many agricultural crops, particularly corn, tomato, and cotton (Metcalf and Metcalf 1993). The moth is monitored in cropping systems with a four component sex pheromone (Klun *et al.* 1980). In the irrigated farming areas of south central Washington, the corn earworm is the key pest of sweet corn, and numerous pesticide applications are required per season to control it. *Heliothis phloxiphaga* (Grote and Robinson) is generally not a pest but is important as a non-target insect that is sometimes captured in corn earworm pheromone traps (Adams 2001, Hoffman *et al.* 1991). *Heliothis phloxiphaga* males respond to the corn earworm pheromone, due to the overlapping chemistries of pheromones of these two species (Kaae *et al.* 1973, Klun *et al.* 1980, Raina *et al.* 1986). Because of their overlapping size and coloration, *H. phloxiphaga* in CEW pheromone traps may be wrongly identified, giving false positive indications for CEW and potentially leading to unnecessary pesticide applications (Adams 2001, Hoffman *et al.* 1991). Photographs of the adult stage of both species are figured by Covell (1984), Powell and Opler (2010), and on the Noctuoidea of Canada Website (Troubridge and Lafontaine 2011).

Monitoring of the male corn earworm moth flight with pheromone traps provides information to growers and field scouts that is used to make pest management decisions. Growers of sweet corn in Washington use the traps to indicate the onset of arrival of corn earworm moths, and the need to begin a spray program. In this area, the corn earworm has one to three generations per year (Mayer *et al.* 1987), while *H. phloxiphaga* may be

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univoltine (Piper and Mulford 1984). Sweet corn is first planted in May in eastern Washington, becomes susceptible to attack by the corn earworm in mid July, and is grown by staggered planting dates into October. Growers need to know when to expect corn earworm moth flight, and when to be concerned with distinguishing corn earworm from *H. phloxiphaga* moths in corn earworm pheromone traps. Seasonal patterns of corn earworm captures in traps have been determined for other geographic and climactic areas (Parajulee *et al*. 2004, Weber and Ferro 1991) but these reports may not be applicable to irrigated agriculture of Washington.

The primary objective of this study was to determine the seasonal occurrences of adult *H. zea* and *H. phloxiphaga* in central Washington. We determined seasonal patterns of moths present as indicated by captures of moths in pheromone-baited traps. In addition, we note responses of the two species to their conspecific and heterospecific sex pheromones. Differences and similarities in the seasonal patterns of the two species should help with interpretation of trap catch data and reduce errors caused by the capture of both species in traps used for corn earworm pest management programs.

MATERIALS AND METHODS

Trapping studies were conducted in 1999 to 2004 in south central Washington. The multicolored (white bucket with yellow cone and green lid) Universal Moth Trap (Great Lakes IPM, Vestaburg, MI) was used, with a 6.4 cm2 piece of Vaportape™ (Hercon Environmental, Emigsville, PA) stapled to the inside wall of the trap bucket to kill captured insects. In all cases, traps were checked and captured insects removed each week, and Vaportape™ and lures were replaced every 4 weeks.

Corn earworm lures were the pheromone identified by Klun *et al*. (1980) consisting of 86.7% (Z)-11-hexadecenal, 3.3% (Z)-9-hexadecenal, 1.7% (Z)-7-hexadecenal, and 8.3% hexadecanal in a total pheromone load of 1.0 mg per septum, following the methods of Halfhill and McDunough (1985). Pheromone lures for *H. phloxiphaga* (Raina *et al*. 1986) were 92% (Z)-11-hexadecenal, 0.4% (Z)-9-hexadecenal, 4.8% hexadecanal, and 2.8% (Z)-11-hexadecen-1-ol in a total pheromone load of 1.0 mg per septum. Pheromone was loaded into red rubber septa (West Co., Lyonville, PA) that had been pre-extracted twice with methylene chloride in a tumbler. Pheromone was applied to septa as a solution in hexane, at a dosage of 200 microliters per septum. Chemicals were purchased from Farchan Chemicals (Atlanta, GA) and Aldrich Chemical Co. (Milwaukee, WI), and all chemicals were 95% or greater purity. The aldehydic pheromone compounds were purified by elution through a silica gel column with 5% ether in hexane. Pheromone dispensers were stored in glass vials in a freezer until placed in traps in the field. Pheromone lures were placed in the plastic baskets provided at the center of the inside of the tops of the traps

Traps were set up early in the season near fields to be planted to corn, and were maintained until the moth flights ended in late autumn. Traps were either hung on fences or from stakes put into the ground, at a height of 0.7 to 1.0 m. Traps were checked each week, and Vaportape™ and pheromone lures were replaced each month. Moths in traps were placed in labeled Ziploc® plastic bags for transport to the laboratory, where moths were sorted, identified, and counted. Voucher specimens are deposited in the James Entomological Collection, Department of Entomology, Washington State University, Pullman, WA.

Season-long monitoring of CEW with pheromone traps. Corn earworm moths were trapped throughout the seasons of 1999-2004, with from 4 to 9 trap sites used per season (Table 1). One trap baited with corn earworm pheromone was placed at each site. Trapping sites were selected based on abundant acreage of commercial sweet corn to be planted nearby. At the end of the season, traps were recovered from the field, washed with hot soapy water, rinsed with tap water, and exposed outside to sun and open air in wooden bins for a minimum of 30 days before indoor winter storage, to reduce risk of long term contamination of the trap by pheromone.

Season-long monitoring of *H.*

***phloxiphaga* with pheromone traps.** *Heliothis phloxiphaga* moths were monitored with traps baited with *H. phloxiphaga* pheromone, during 1999-2001. Trapping sites, trapping dates, and trap maintenance were the same as those indicated above for corn earworm pheromone traps during the same years (Table 1). One trap baited with *H. phloxiphaga* pheromone was placed at each site, more than 90 meters from the corn earworm pheromone trap.

We also report *H. phloxiphaga* moths captured in traps baited with CEW pheromone from 1999-2004, and CEW moths captured in traps baited with *H. phloxiphaga* pheromone, from 1999-2001. Statistical comparisons were made of numbers of CEW and *H. phloxiphaga* moths trapped in response to conspecific versus heterospecific sex pheromone lures, using a paired t-test.

Table 1.
Dates and lures for season long monitoring of corn earworm.

Year	Start Date	No. of Sites	Site Locations	Pheromones tested
1999	17 May	9	Yakima Co., Mabton & Toppenish Benton Co., Prosser	CEW *H. phloxiphaga*
2000	20 April	5	Grant Co., Mattawa	CEW *H. phloxiphaga*
2001	16 April	4	Grant Co., Moses L. Franklin Co., Pasco	CEW *H. phloxiphaga*
2002	25 March	4	Yakima Co., Wapato, Granger, Donald, Toppenish	CEW
2003	29 March	4	Yakima Co., Toppenish & Moxee Benton Co., Prosser	CEW
2004	2 April	4	Yakima Co., Toppenish & Moxee Benton Co., Prosser	CEW

RESULTS

Generally, first male corn earworm moths were captured in late May, and males were present continuously through the summer into October (Figure 1). In all years, maximum numbers of male moths were captured in August. However, in 2002 and 2003, a smaller peak of activity was apparent in June. Numbers of moths per trap per week varied widely from year to year, with a maximum of over 250 per trap per week in 2002, but under 70 moths per trap per week in 1999, 2000, and 2003.

For 1999-2001, data for *H. phloxiphaga* are from traps baited with conspecific pheromone, and for 2002-2004, data for *H. phloxiphaga* are from traps baited with CEW pheromone. Generally, male *H. phloxiphaga* moths were first captured in pheromone traps in April (Figure 2). In 1999 and 2000, traps were not placed in the field early enough to determine the onset of *H. phloxiphaga* flight and males were captured during the first week of the study. In all 6 years, there were two separate periods of flight activity of male *H. phloxiphaga*. The first period was in late April to early June, and the second period was mid July to late August. Numbers of moths trapped varied greatly from year to year, with a maximum of over 24 male moths per trap per week in 2004, and a maximum of fewer than 5 moths per week in 1999.

Traps baited with CEW pheromone captured primarily CEW moths, and traps baited with *H. phloxiphaga* pheromone captured primarily *H. phloxiphaga* (Table 2). In 1999, 2000, and 2001, when the pheromones of both CEW and *H. phloxiphaga* were maintained throughout the season, CEW moths were captured primarily in traps baited with the CEW pheromone, with relatively few captured in traps baited with the *H. phloxiphaga* pheromone. Numbers of male *H. phloxiphaga* captured were numerically but not significantly greater in traps baited with the *H. phloxiphaga* pheromone compared to traps baited with the CEW pheromone (Table 2).

DISCUSSION

The primary objective of this study was to characterize the seasonal patterns of captures of CEW and *H. phloxiphaga* moths in traps in southcentral Washington as an indicator of adult moth presence in corn fields. Particular aspects of moth seasonal patterns that are potentially of interest include the onset of moth flight in the spring and cessation in autumn, peak activity periods, and numbers of generation per year. In this case, we are also interested in determining periods of risk of misidentifying *H. phloxiphaga* as CEW, in relation to CEW pest management. Although numbers of CEW moths captured in pheromone traps varied greatly from year to year, the cessation, termination, and peak periods of moth activity were similar throughout this 6 year period. The period during which corn earworm moths were active broadly encompasses the entire period during

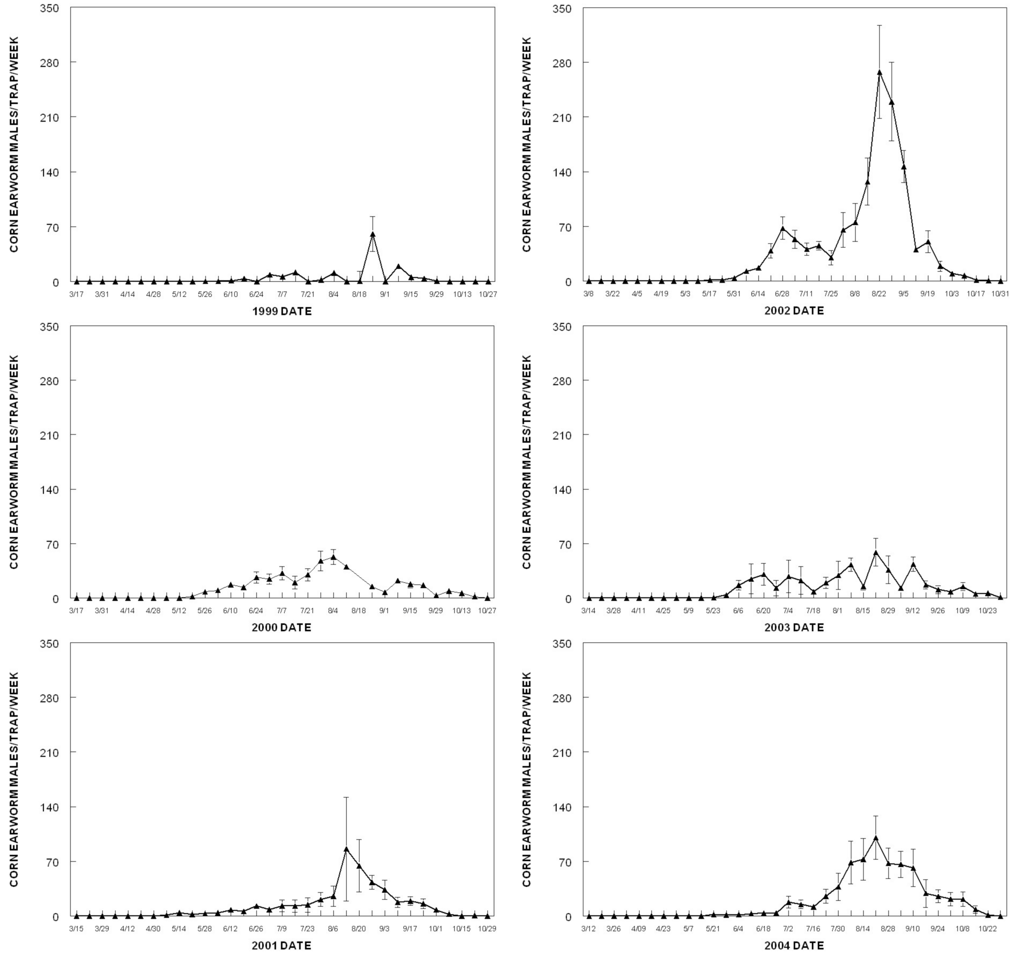

Figure 1. Mean (± SE) numbers of male corn earworm moths captured per week per trap, in traps baited with corn earworm pheromone, for 1999, 2000, 2001, 2002, 2003, and 2004.

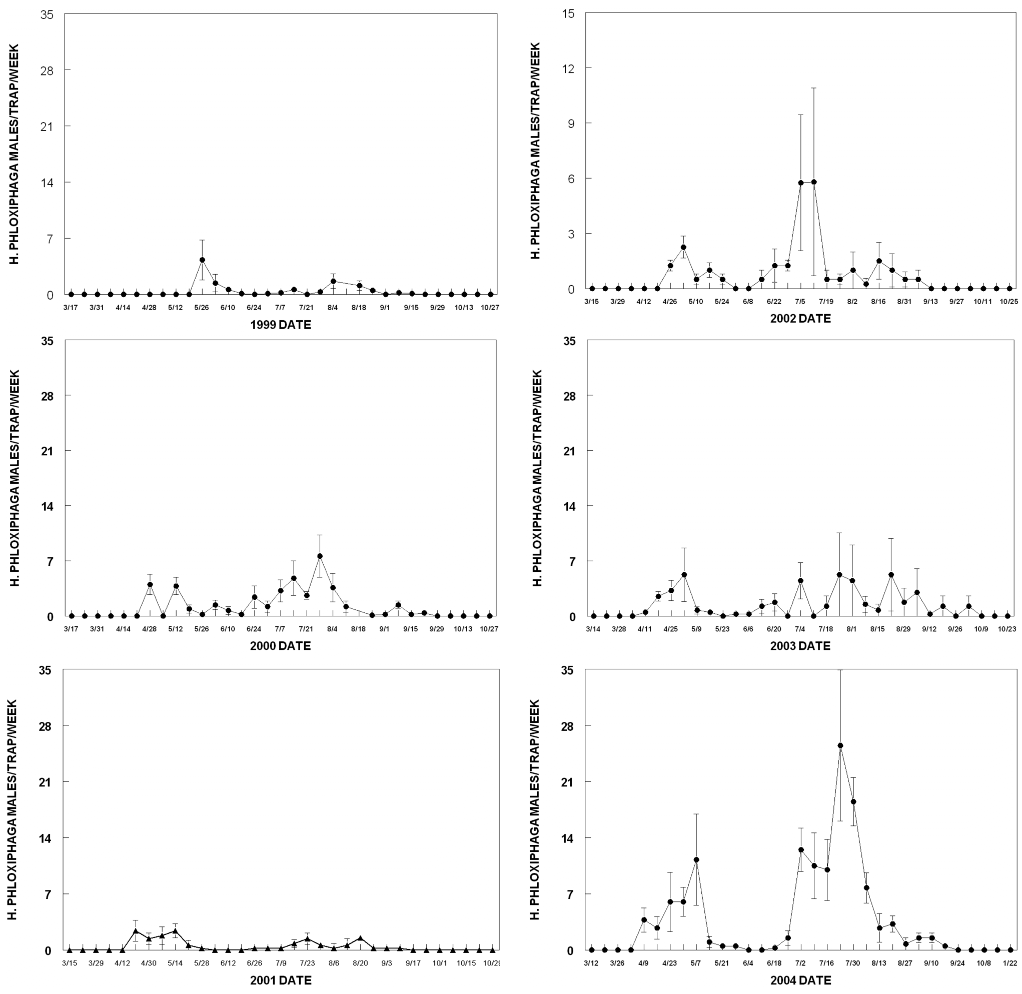

Figure 2. Mean (± SEM) numbers of male *H. phloxiphaga* moths captured per week per trap, in traps baited with *H. phloxiphaga* pheromone (1999, 2000 and 2001) or corn earworm pheromone (2002, 2003, 2004).

which corn is grown in this same area. Corn is normally first planted after last frost, in mid to late May, and staggered plantings and harvesting continue into early October. However, corn is a suitable oviposition site for CEW beginning with the silking stage, which starts in late June. Earlier in the season, CEW moths might be infesting alternate host plants, possibly weed and wild flower species (Hardwick 1965, 1996; Neunzig 1963; Robinson *et al*. 2002). It is assumed that the end of moth flight in autumn may occur primarily as a result of decreasing temperatures making moth flight impossible. In contrast to evidence for CEW migrating from south to north (Hartstack *et al.* 1982; Westbrook *et al*. 1997), there is no documentation of north to south migration. If such a migration occurs, it could explain in part the disappearance of the moth in early autumn in south central Washington.

Mayer *et al*. (1987) reported 1-3 generations of CEW per year in Washington. Our data show nearly continuous moth activity for 5 months, from late May into mid to late October, without evidence of distinct generations. Corn earworm may overwinter in the southern Columbia Basin of Washington, as pupae in soil (Eichman 1940, Klostermeyer 1968), first emerging in May. The interpretation of trap catch data may be complicated by immigration of CEW populations from the southwestern U. S. In other areas of North America, CEW moths migrate (Hartstack *et al*. 1982; Hendrix *et al*. 1987; Lingren *et al.* 1993, 1994; Westbrook *et al*. 1997). Strong increases in numbers of male CEW moths in pheromone traps in August may have been due to reproduction by earlier emerging moths, and/or migrating moths that arrive in south central Washington with infrequent weather fronts.

The seasonal activity and abundance of the corn earworm moth varies geographically, probably in response to climactic factors and their impact on migration, reproduction, and other behaviors, as well as regional makeup and abundance of crops and crop planting and harvest cycles. The amplitudes of the seasonal patterns of catches of CEW moths in pheromone traps in south central Washington were small compared to that observed in Texas by Parajulee *et al*. (2004). Captures of moths in pheromone traps often began in April in Texas, compared to May in Washington, and ended in October as it did in our study in Washington. In Mississippi, CEW males were captured in pheromone traps sporadically from early June to the end of September (Hayes 1991). In Massachusetts, CEW moth flight appears to begin much later than in south central Washington despite a similar latitude. Weber and Ferro (1991) captured CEW moths in pheromone traps in Massachusetts from early July into early September, which is a seasonal activity period that is nearly 2 months shorter than seen in our study.

Piper and Mulford (1984) reported that *H. phloxiphaga* was univoltine in Washington. The data presented here indicate consistently over the 6 years that there were two periods of increased catches of moths in traps, indicating possibly two generations per year. The apparent two maxima of activity indicated by pheromone traps suggests that a first adult generation occurred in April/May and a second generation in July/August. However, Hoffman *et al.* (1991) did not see more than one peak of captures of *H. phloxiphaga* in corn earworm pheromone traps in California, although adult activity was noted over a period of 6 months, from February to September. Certainly, multiple generations of a moth species can occur within a season

Table 2

Mean (±SE) numbers of male corn earworm and *H. phloxiphaga* moths captured per season per trap baited with corn earworm and *H. phloxiphaga* sex pheromones.

Moth species captured	**Corn earworm pheromone**	*H. phloxiphaga* **pheromone**	**n**
1999			
Corn earworm	218.3 ± 64.2a	1.4 ± 1.1b	9
H. phloxiphaga	6.9 ± 2.4a	12.4 ± 3.9a	9
2000			
Corn earworm	427.6 ± 52.3a	3.8 ± 1.0b	5
H. phloxiphaga	25.2 ± 6.4a	44.2 ± 10.9a	5
2001			
Corn earworm	415.8 ± 144.0a	2.5 ± 0.9b	4
H. phloxiphaga	22.3 ± 5.7a	16.0 ± 5.8a	4

Means within a row followed by the same letter are not significantly different by a paired t-test at $P < 0.05$.

without the appearance of distinct separated periods of flight indicated in pheromone traps.

In all six years of our study, the first flight of *H. phloxiphaga* began about one month before the first catches of CEW moths in traps, and captures of *H. phloxiphaga* moths ended about one month before the last captures of CEW moths. Peak numbers of possible second flight *H. phloxiphaga* populations overlapped somewhat with peak numbers of CEW in early August, although the numbers of *H. phloxiphaga* in *H. phloxiphaga* pheromone traps were considerably less than CEW moths trapped with corn earworm pheromone. It appears then that CEW monitoring traps in May might easily provide misleading information from the capture of *H. phloxiphaga* misidentified as CEW, but before the expected appearance of CEW. Also, in August, *H. phloxiphaga* captured in CEW pheromone traps may inflate counts of CEW trap catch, if misidentified. However, those numbers would usually be minor in relation to the numbers of CEW moths trapped at that time. It is most important to positively identify the two species early in the season, and again in late summer when both are present, but in situations where corn earworm populations are expected to be low.

Although the chemistry of the *H. phloxiphaga* sex pheromone overlaps with that of the CEW pheromone, *H. phloxiphaga* responses to the CEW lure are not consistently a problem with CEW monitoring programs in North America. Weber and Ferro (1991) found 5 non-target species of noctuids captured in CEW monitoring traps in Massachusetts, but did not indicate the trapping of *H. phloxiphaga*. Chapin *et al*. (1997) reported non-target moths captured in corn earworm traps, but captured only one *H. phloxiphaga* moth compared to over 25,000 CEW. However, in eastern Washington, *H. phloxiphaga* is consistently present throughout much of the corn growing season and is routinely captured in corn earworm pheromone traps (Adams 2001), and Hoffman *et al.* (1991) trapped it in sweet corn fields throughout California. Growers can reduce costs and pesticide used by distinguishing the two species when captured in corn earworm traps, and by recognizing that corn earworm are unlikely to be present before late May.

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