2004 BELTWIDE COTTON CONFERENCES, SAN ANTONIO, TX – JANUARY 5-9

EFFECT OF HOST PLANT SPECIES ON DIAPAUSE IN THE TARNISHED PLANT BUG

G.L. Snodgrass and C.A. Abel
Southern Insect Management Research Unit
USDA-ARS
Stoneville, MS

Abstract

Fourth and fifth instars of the tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), were collected from wild hosts in the fall and reared in the laboratory to adults using their collection host as food. Adults were dissected when 7 d of age or older to determine whether they were reproductive or in diapause. Nymphs reared on pigweed, *Amaranthus spp.*, goldenrod, *Solidago altissima* L., and white heath aster, *Aster pilosus* Willdenow, in October and early November 2002 produced adults which ranged from 48 to 80% in diapause. Adults from rearing nymphs on these same host species in October 2003 were mostly (>95%) in diapause. The lower percentages of adults in diapause found in 2002 were thought to be due to higher quality of host plants which resulted from excellent growing conditions (above average temperatures and rainfall). The percentage of adults in diapause produced on pinkweed, *Polygonum pensylvanicum* L., was consistently higher in both years compared to the percentages of adults in diapause found on the other hosts. Pinkweed grows primarily in wet areas in or near ditches and the quality of this host was probably less affected by temperature and rainfall than the other hosts studied. Reproductive females reared from all hosts in September had lower amounts of fat in reproductive females reared from these hosts in October and November. The fat content of the reproductive females reared in October and November was characteristic of adults in diapause, although their ovaries were expanded with mature or developing eggs and/or they were recently mated. The role that the reproductive females produced in October and November play in the adaptation of plant bugs to their winter habitat is unknown. Host plant species was found to influence the percentage of adult plant bugs which entered diapause in September through November in the mid-South, and host plant quality was probably another determining factor.

Introduction

The tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), is an economically important pest of many crops in the United States (Young 1986) and is a key pest of cotton, *Gossypium hirsutum* L., in the mid-South (Scott et al. 1985). In the Mississippi River Delta of Arkansas, Louisiana, and Mississippi, tarnished plant bugs can be collected from 169 host plant species representing 36 plant families (Snodgrass et al. 1984). They overwinter as diapausing adults in North America. In the mid-South reproductive diapause is broken by part of the overwintering population in December (Snodgrass 2003). These adults are active on a few winter host plant species, primarily henbit, *Lamium amplexicaule* L. Nymphs can be found on henbit in January with a new generation of adults being produced by the middle of March in winters with normal or above normal temperatures. The remainder of the overwintering population is found in plant debris and these adults break diapause about one month later during January. This overwintering strategy allows tarnished plant bugs to utilize winter and spring hosts for population increases. Nymphs are the life stage sensitive to changes in day length, and newly emerged nymphs reared at constant day lengths of 12.5 h or less produced adults in diapause in the laboratory (Bariola 1969). Nymphs that develop on wild hosts in the field begin producing a mixture of reproductive and diapausing adults in late August in the mid-South, and by October most adults produced on wild hosts were in diapause (Snodgrass 2003). Villavaso and Snodgrass (2004) reared nymphs in environmental cabinets programmed to simulate dynamic photoperiods. They estimated the critical photoperiod (photoperiod at which 50% of the population entered diapause) to begin just prior to 22 August. Snodgrass (2003) estimated the critical photoperiod using field collected bugs to be around 12 September at Stoneville, MS. Diapause is a critical part of the biology of the tarnished plant bug, and in the mid-South it allows plant bugs to have reproductive adults present on wild hosts every month of the year (Snodgrass 2003). Increases in plant bug populations can occur on wild hosts and they are critical to their pest status in crops (Snodgrass et al. 1984). These increases are determined by the availability and abundance of wild hosts in cultivated fields and in marginal areas in the mid-South. Wild hosts are especially important in population increases in the fall and in January through April, because cultivated crops are not available as reproductive hosts during these times.

Diet is a major factor regulating diapause in a few insect species (Tauber et al. 1986). The effect of host-plant quality on diapause has been infrequently studied, however, it has been found to interact with other factors such as photoperiod and temperature in the production of diapause in some insects. Host-plant quality is one of four factors important in diapause induction in the codling moth, *Cydia pomonella* (L.) (Riedl 1983), and is one of three factors affecting diapause in the alfalfa lady beetle, *Subcoccinella 24-punctata* (Ali and Saringer 1975). These two species have a higher incidence of diapause after they feed on non-preferred hosts. Larvae of the obliquebanded leafroller, *Choristoneura rosaceana* (Harris), are more likely to produce a second generation (not enter diapause) on their preferred host chokecherry, *Prunus virginiana* L., than were larvae fed three other plant species

(Hunter and McNeil 1997). Snodgrass et al. (1984) found that tarnished plant bugs prefer host plants with flower buds or blooms. Nymphs were seldom collected on a host unless the host was flowering or developing seeds or fruit. Wild hosts which produced large numbers of blooms and seeds supported higher numbers of plant bugs than other host plants. In the late summer and fall in the mid-South, the most abundant host plants on which adults in diapause could be produced included horseweed, *Conyza canadensis* (L.), giant ragweed, *Ambrosia trifida* L., pinkweed, *Polygonum pensylvanicum* L., goldenrod, *Solidago altissima* L., white heath aster, *Aster pilosus* Willdenow, and pigweed, *Amaranthus* spp. Pinkweed and pigweed begin blooming in July and can be found in bloom over a five-month period into November. Horseweed blooms from July through September, while giant ragweed blooms from July through October. Goldenrod and white heath aster both bloom in October and November. The current study was conducted to determine the contibution that each of these host plant species make to the overwintering plant bug population by determining percentage in diapause among adults that developed on each host during late summer and fall.

Materials and Methods

Weather data were obtained from the Stoneville Weather Station, Delta Branch Research and Experiment Station, Stoneville, MS. A summary of weather data for Stoneville presenting average data for 1964-1993 is found in Boykin et al. (1995), and 30-yr average data and day length were taken from this publication. Tarnished plant bugs were collected from wild hosts near Stoneville in Washington County, MS. The study was begun in 2002 when fourth and fifth instar tarnished plant bug nymphs could first be collected on all of the fall host plant species being studied. Nymphs were collected from pigweed (mainly *Amaranthus spinosus* L.), white heath aster, pinkweed, and goldenrod with a sweep net on 23 and 31 October, and 8, 14, and 21 November. These nymphs were reared for 3-4 d indoors on a table near a window where they received natural light and day length. The room was also illuminated with overhead fluorescent lights from 0700 to 1530 on weekdays. Humidity was not controlled and temperature was 25 ± 4°C. Nymphs were held in clear 0.55- liter plastic containers with clear lids and fed stems with attached leaves and flowers (along with developing seeds if they were also present) of the host plant species they were collected from. After flowering, the plant bugs were fed stems with attached leaves and developing seeds if nymphs were still found on the host plant. Food was changed as needed and adults were collected daily as they emerged. Adults were also held in the clear plastic containers on the table with the nymphs being reared, and fed the same food they received as nymphs or broccoli, *Brassica oleracea* L. var *botrytis* L.

Adults were killed in 70% ethanol and dissected in water when 7 d of age or older to determine their reproductive status. Failure of the reproductive organs to enlarge, and hypertrophy of the fat body were the criteria used to determine diapause (Lees 1955). Tarnished plant bugs having characteristics of both diapausing and reproductive adults were also found. Such adults, both male and female, still had large to moderately sized fat bodies with reproductive organs in different states of maturity. Females were considered to be reproductive if the ovaries had one or more mature eggs (eggs in which the operculum was developed), or enlarged ovaries with developing oocytes, or it had been recently mated [the genital pouch was greatly enlarged (Strong et al. 1970)]. Males were considered to be reproductive if white fluid was visible in the accessory glands, and the accessory glands had begun to enlarge. An obvious size difference between the testes of reproductive and diapausing males was not always present, however, in most cases the testes of a diapausing male were covered with a sheath of fatty tissue which made it difficult to see the testicular lobes (Villivaso and Snodgrass 2004). Testes of males were examined for this sheath as part of the determination of their reproductive status. Males and females were rated for their fat content using a rating of high if their abdomen was full of globular whitish fat; medium if globular fat was present in lesser amounts that did not fill the abdomen; and low if no fat, or some non-globular fat was present.

The study was expanded in 2003 to include horseweed and giant ragweed along with pigweed and pinkweed during the transitional month of September when a mixture of reproductive and diapausing adults are produced on these hosts (Snodgrass 2003). Fourth and fifth instar nymphs were collected from pigweed (mainly *A. spinosus*) and pinkweed weekly during September, October, and November. They were collected weekly from giant ragweed and horseweed in September and the first week of October (giant ragweed and horseweed matured in late September and nymphs could not be collected after 3 October). Nymphs were collected from goldenrod on 10, 17 and 28 October and 3 and 10 November. Nymphs from white heath aster were collected on the same dates as the collections from goldenrod, except that on 10 October nymphs on white heath aster were too young to use. The same rearing and dissection procedures used in 2002 were again used in 2003 to determine the reproductive status of the adults obtained from the different hosts.

Results

The fall of 2002 was an excellent growing season for wild hosts at Stoneville. Rainfall from August through October was higher than normal, with amounts in September and October more than twice the 30-yr average (Table 1). Temperatures were higher than the 30-yr average in August through October, and a little below average in November. Nymphs collected from pinkweed

produced mostly (94-96%) diapausing adults from 23 October through 8 November 2002 (Fig. 1). The percentage of adults in diapause produced on pinkweed declined rapidly from 8 November (94%) to 21 November (44%), the last collection date on which nymphs were found. The percentage of adults in diapause from pigweed was highest (82%) on 23 October, then declined each week to 33% on 21 November. On white heath aster and goldenrod, the percentage in diapause increased from 63 and 48%, respectively, on 23 October, to 75 and 59%, respectively, on 8 November. The number of adults in diapause then declined to 50% on 14 November (white heath aster) and 27% on 21 November (goldenrod).

Temperatures were well above the 30-yr average with below normal rainfall in August and November 2003 (Table 1). Rainfall was about 1 to 1.5 inches higher than the 30-yr average with slightly higher average temperatures in September and October. The percentages of adults in diapause produced from nymphs collected and reared on pigweed, giant ragweed, and horseweed were similar each week from 4 September through 3 October (Fig. 2). These percentages increased from 2-3% on 4 September to 68 to 84% on 3 October (the last date on which nymphs were collected on horseweed and giant ragweed). The percentage of adults collected and reared on pinkweed during this 5-wk period was consistently higher (an average of 13.1%) than on the other three hosts. Adults from nymphs collected and reared on pinkweed, pigweed, white heath aster, and goldenrod were all 95% or greater in diapause from 10 October through 28 October. The percentage in diapause then declined to 70% for pinkweed on 10 November and 55, 71, and 52% for pigweed, goldenrod, and white heath aster, respectively, on 10 November, the last date nymphs were collected.

The fat content of reproductive plant bugs which were collected and reared in September differed from that found in October and November (Table 2). In September of 2003, 33, 53.6, and 13.4% of the 412 reproductive females found had their fat content rated as low, moderate, or high, respectively. In October of 2002 and 2003, 3.6, 40.0, and 56.4% of the 55 reproductive females (for both years combined) had their fat content rated as low, moderate, or high, respectively. In November (for both years combined), 3.9, 16.3, and 79.8% of the 178 reproductive females had their fat content rated as low, moderate, or high, respectively. Data for the fat content of reproductive males during the three-month period is not shown.

Discussion

Nymphs which developed on pinkweed produced numbers of adults in diapause above 90% in October and early November 2002, and throughout October 2003 (Figs. 1 and 2). It was the only host on which this occurred in both years. Weather probably had less of an effect on the quality of pinkweed as a plant bug host than it did on the other hosts. Pinkweed grows best in areas such as ditches that stay wet most of the year, and its growth is probably less affected by rainfall and temperature in this habitat. Pigweed, goldenrod, and white heath aster also produced numbers of adults in diapause above 90% in October 2003 (Fig. 2), but not in 2002 (Fig. 1). Numbers of adults produced in diapause in 2002 on white heath aster peaked at 74% on 8 November, while those produced in diapause on goldenrod never exceeded 60%. The weather in 2002 in October and November was ideal for plant growth with abundant rainfall and above average temperatures. Under these conditions, a higher percentage of reproductive adults were produced in October and early November in 2002 as compared to October in 2003. This response is similar to the response of the obliquebanded leafroller which was found to produce a second generation (not enter diapause) when its larvae developed on a high quality host, such as chokecherry (Hunter and McNeil 1997). The percentages of adults reared from nymphs on giant ragweed and horseweed peaked at 68 and 78%, respectively, in the first week of October 2003 (the last week in which nymphs were collected). However, these host species make a significant contribution to the overwintering plant bug population because they are abundant and support high populations of plant bugs.

In some insects, such as the codling moth, alfalfa lady beetle, and obliquebanded leafroller (Riedl 1983, Ali and Saringer 1975, Hunter and McNeil 1997) as the quality of the host declined adults produced on the hosts had a higher incidence of diapause. However, this response was not found for tarnished plant bugs in November of the current study. During November of both years, as the quality of the hosts declined (they finished flowering) fewer adults were in diapause. However, most of the reproductive females produced in October and November of 2002 and 2003 had moderate to high fat content (96.4% in October and 96.1% in November for both years combined) (Table 2). They differed from the reproductive females produced in September of which 86.6% had low to moderate fat content in 2003. Low fat content is characteristic of reproductive females that develop in the field on wild hosts under non-diapausing inducing photoperiods, while high fat content is characteristic of adults in diapause. Bariola (1969) reared plant bug nymphs through the first four nymphal instars at 25°C at 12:12 (L:D) (a diapause inducing photoperiod), then reared the fifth instar nymphs and young adults at a non-diapause inducing photoperiod of 13.5: 10.5 (L:D). The adults when dissected after two weeks were all reproductive but had hypertrophied fat bodies characteristic of adults in diapause. He thought that the 12 h photoperiod was a diapause inducing stimulus received by the earlier nymphal instars which caused the buildup of fat. Exposure of fifth instars and young adults to a non-diapause inducing day length for two weeks caused them to become reproductive. Exposure to longer day lengths does not occur in field populations of plant bugs in October and November. During these months day length and average temperatures decrease, and quality of the host plants declines as they mature. The interaction

of these environmental factors was probably the cue that produced reproductive adults with hypertrophied fat bodies. Reproductive adults with hypertrophied fat bodies are commonly collected from henbit (which begins blooming in late November in the mid-South) in the mid-South during December. The number of reproductive adults on henbit increases each week in December as this population breaks diapause (Snodgrass 2003). These reproductive adults with hypertrophied fat bodies are transitional forms that occur as the adults change from being in diapause to being reproductive. Over 90% of adults found on henbit were reproductive by the last week in December in 1999 and 2001 at Stoneville, and by the second week in January in these years all of the females dissected had fully developed eggs (Snodgrass 2003). It is possible that the reproductive adults with hypertrophied fat bodies produced in October and November of the current study remained on their developmental hosts until they were unsuitable as food hosts or the hosts were killed by cold weather. The reproductive adults could then move to henbit, or if henbit was unavailable, they might be able to stop reproductive development and survive the winter using energy stored in their fat body. However, the role that they serve in the adaptation of plant bugs to their winter environment is unknown.

In summary, the study showed that the numbers of adult plant bugs in diapause produced on wild hosts in the fall varied with each host and probably their quality. Host quality for pigweed, goldenrod, and white heath aster appeared to be affected by temperature and rainfall, and numbers of diapausing adults produced on these hosts were different in the two years they were studied. Adults produced on pinkweed had a consistently higher percentage of adults in diapause than the other hosts studied.

References Cited

Ali, M. A., and G. Saringer. 1975. Factors regulating diapause in alfalfa ladybird, *Subcoccinella 24-punctata* L. (Col., Coccinellidae). Acta Phytopathology, Academy of Sciences of Hungary 10: 407-415.

Bariola, L. A. 1969. The biology of the tarnished plant bug, *Lygus lineolaris* (Beauvois), and its nature of damage and control on cotton. Ph. D. Dissertation, Texas A&M University, College Station.

Boykin, D. L., R. R. Carle,C. D. Ranney, and R. Shanklin. 1995. Weather data summary for 1964-1993 at Stoneville, Mississippi. Tech. Bull. 201. Mississippi Agr. and For. Expt. Sta., Mississippi State, MS.

Hunter, M. D., and J. N. McNeil. 1997. Host-plant quality influences diapause and voltinism in a polyphagus insect herbivore. Ecology 78: 977-986.

Lees, A. D. 1955. The physiology of diapause in arthropods. Cambridge University Press, Cambridge, United Kingdom.
Riedl, H. 1983. Analysis of codling moth phenology in relation to latitude, climate and food availability. *In* Diapause and life cycle strategies in insects (eds. V. K. Brown and I. Hodek) pp. 233-252. Junk, The Hague, The Netherlands.

Scott, W. P., J. W. Smith, and G. L. Snodgrass. 1985. The tarnished plant bug (Hemiptera: Miridae); a key pest of cotton in the Mississippi Delta, pp. 164-167. *In* Proceedings Beltwide Cotton Production Reseasrch Conference, New Orleans, LA. National Cotton Council, Memphis, TN.

Snodgrass, G. L. 2003. Role of reproductive diapause in the adaptation of the tarnished plant bug (Heteroptera: Miridae) to its winter habitat in the Mississippi River Delta. Environ. Entomol. 32: 945-952.

Snodgrass, G. L., W. P. Scott, and J. W. Smith. 1984. Host plants and seasonal distribution of the tarnished plant bug (Heteroptera: Miridae) in the delta of Arkansas, Louisiana, and Mississippi. Environ. Entomol. 13: 110-116.

Strong, F. E., J. A. Sheldahl, P. R. Hughes, E. M. K. Hussein. 19770. Reproductive biology of *Lygus hesperus* Knight. Hilgardia 40: 105-147.

Tauber, M. J., C. A. Tauber, and S. Masaki. 1986. Seasonal adaptations of insects. Oxford University Press, New York.

Villavaso, E. J., and G. L. Snodgrass. 2004. Incidence of diapause in tarnished plant bugs, *Lygus lineolaris* (Palisot de Beauvois), in dynamic-photoperiod environmental cabinets. (Submitted, J. Entomol. Sci.)

Young, O. P. 1986. Host plants of the tarnished plant bug Lygus lineolaris (Heteroptera: Miridae). Ann. Entomol. Soc. Am. 79: 747-762.

Table 1. Temperatures and rainfall at Stoneville, Mississippi in 2002 and 2003 along with 30-yr averages.

Year	Month	Mean daily high temperature (°C)	Mean daily low temperature (°C)	Rainfall (inches)
2002	August	33.6 (32.3)[a]	21.7 (21.0)	2.77 (2.48)
	September	31.7 (29.4)	19.7 (17.2)	7.73 (3.30)
	October	23.2 (24.1)	14.3 (10.7)	7.05 (3.10)
	November	16.1 (17.6)	4.9 (6.1)	3.42 (5.40)
2003	August	34.1 (32.3)	22.2 (21.0)	1.53 (2.48)
	September	30.2 (29.4)	17.3 (17.2)	4.94 (3.30)
	October	25.8 (24.1)	12.8 (10.7)	3.97 (3.10)
	November	20.7 (17.6)	8.7 (6.1)	3.76 (5.40)

a. ( ) show the 30-yr average high or low temperature and rainfall.

Table 2. Fat content of reproductive female tarnished plant bugs collected and reared on various wild hosts.

		Fat content								
		September			October			November		
		L[a]	M	H	L	M	H	L	M	H
2002	N	–	–	–	0.0	9.0	30.0	0.0	17.0	107.0
	%	–	–	–	0.0	23.1	76.9	0.0	15.9	84.1
2003	N	136.0	221.0	55.0	2.0	13.0	1.0	7.0	12.0	52.0
	%	33.0	53.6	13.4	12.5	81.3	6.3	9.9	16.9	73.2
Both years	N	136.0	221.0	55.0	2.0	22.0	31.0	7.0	29.0	142.0
	%	33.0	53.6	13.4	3.6	40.0	56.4	3.9	16.3	79.8

a. L = low, no fat or some non-globular fat; M = moderate, globular fat present but it does not fill abdomen; H = high, globular fat fills abdomen.

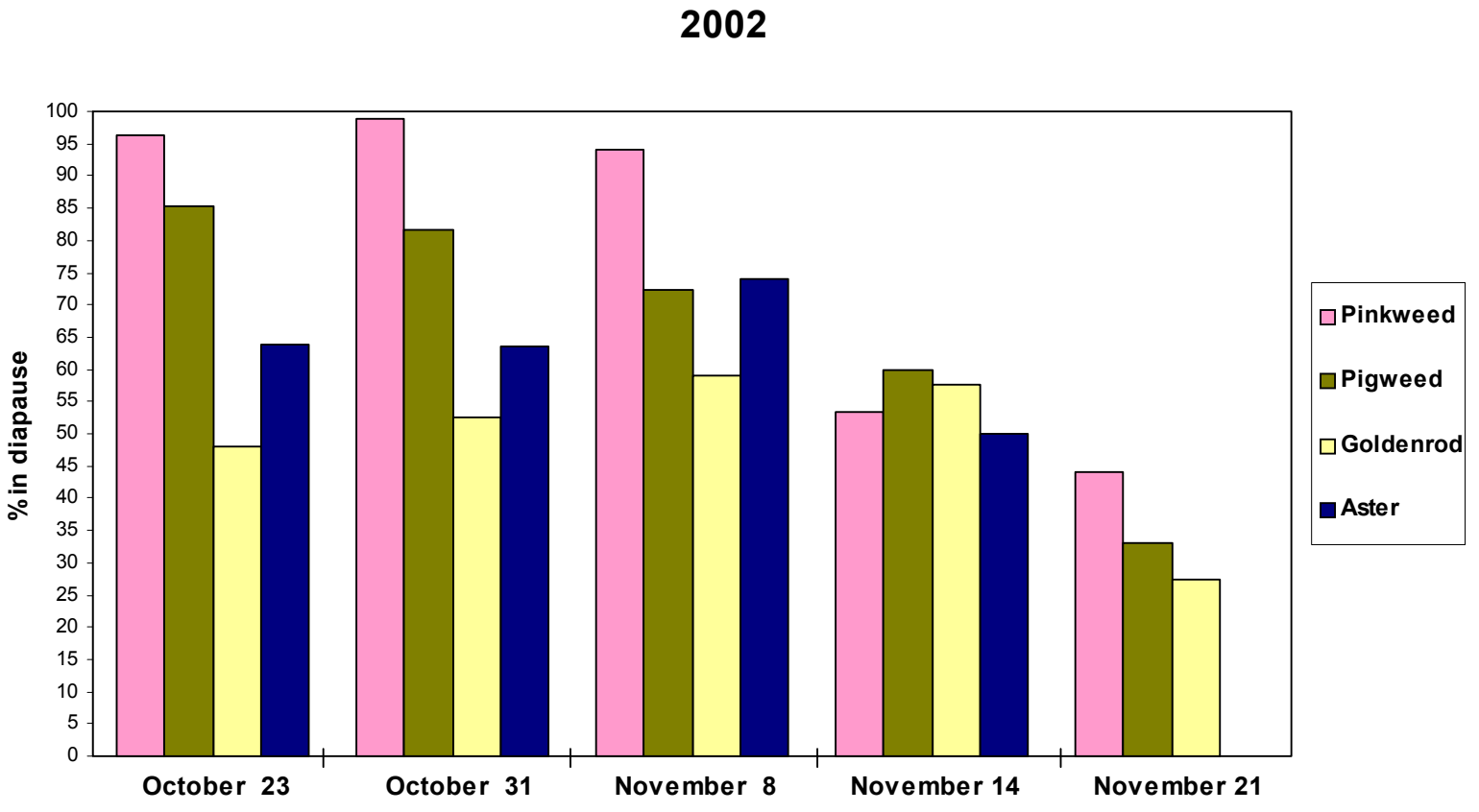

Figure 1. Percentage of adult tarnished plant bugs in diapause collected as fourth and fifth instar nymphs and reared on their collection host at Stoneville, MS in 2002.

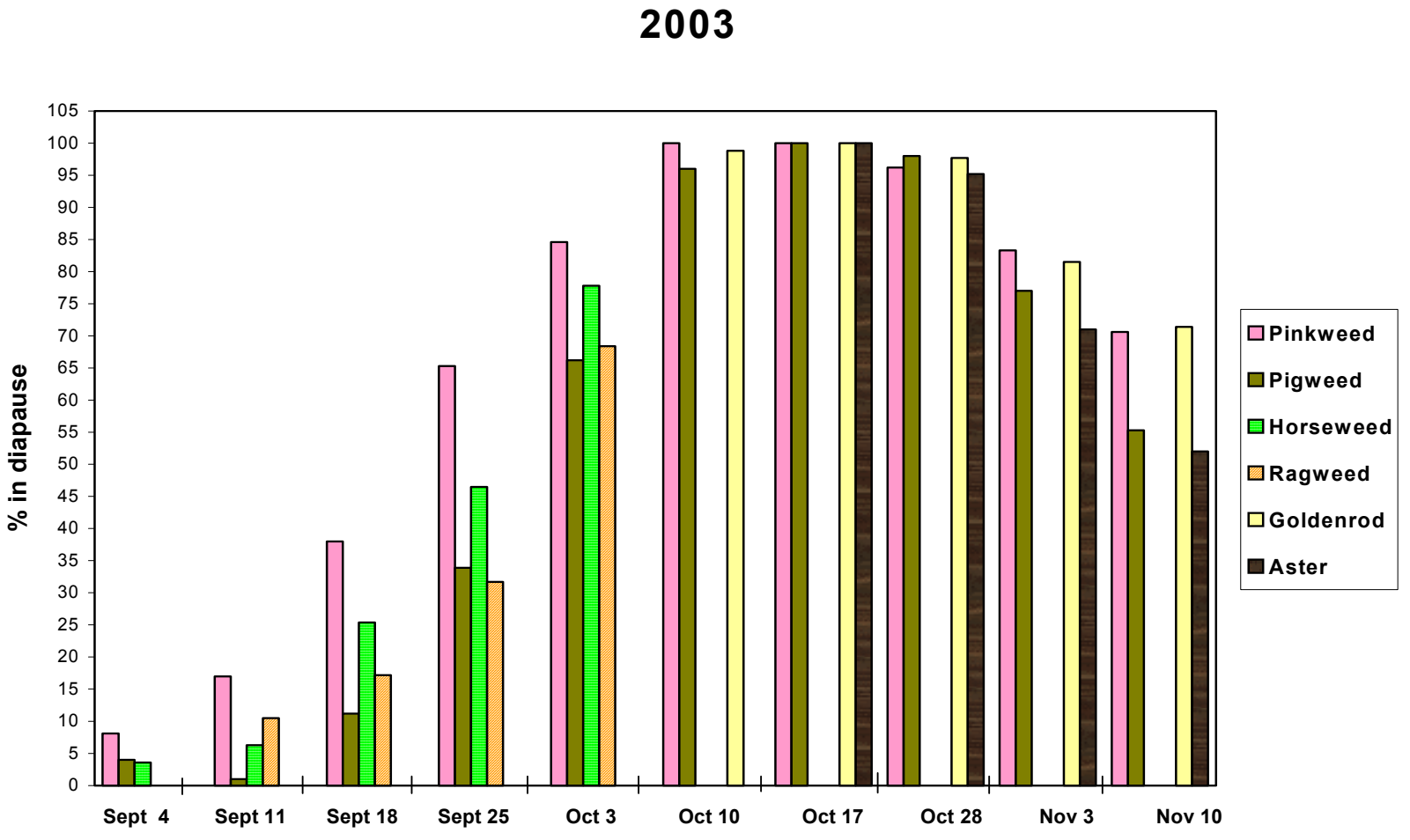

Figure 2. Percentage of adult tarnished plant bugs in diapause collected as fourth or fifth instar nymphs and reared on their collection host at Stoneville, MS in 2003.