Conditions for Short-Term Storage of Field-Collected Spined Soldier Bug, *Podisus maculiventris* (Say) (Heteroptera: Pentatomidae), Adults Prior to Augmentative Release[1]

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Abstract The date at which spined soldier bugs, **Podisus maculiventris** (Say) (Heteroptera: Pentatomidae), can be trapped for augmentative release against overwintered Colorado potato beetle, *Leptinotarsa decemlineata* (Say) (Coleoptera: Chrysomelidae), may be up to 5 wks earlier than the date of peak Colorado potato beetle emergence, necessitating storage of field-collected spined soldier bugs prior to release. The effects of temperature, photoperiod, and food on spined soldier bug survivorship and fecundity during and after a 5-wk storage period were investigated. In general, unfed spined soldier bugs had greater mortality and reduced fecundity compared with those fed string beans and mealworm larvae during storage. Temperature and photoperiod generally had no effect. However, female spined soldier bug survivorship was greater among unfed insects stored at 5°C compared with those stored at 15°C. Therefore, household refrigerators can be used for short-term storage of field-collected spined soldier bugs. Even when stored spined soldier bug females are fed, fecundity is low (14 nymphs per female originally collected). This may limit the use of field-collected spined soldier bugs for augmentative release against Colorado potato beetle to relatively small plantings of potatoes.

Key Words Spined soldier bug, *Podisus maculiventris,* predator, Colorado potato beetle, *Leptinotarsa decemlineata,* biological control, augmentation, storage, pheromone

The spined soldier bug, *Podisus maculiventris* (Say) (Heteroptera: Pentatomidae), is a generalist predator with a recorded host range that includes eight orders of insects (McPherson 1982). The Colorado potato beetle, *Leptinotarsa decemlineata* (Say) (Coleoptera: Chrysomelidae), is one of many pest species reported to be attacked by this predator (Heimpel and Hough-Goldstein 1992). Augmentative releases of spined soldier bugs against Colorado potato beetle have been conducted with varying degrees of success (Biever and Chauvin 1992a, b, Tipping et al. 1999, Aldrich and Cantelo 1999). The availability of a synthetic pheromone that can be used to attract wild spined soldier bug adults in large numbers in the spring (Aldrich et al. 1984, Aldrich 1995) presents interesting possibilities for augmenting spined soldier bug populations without the expense and labor required to artificially rear the preda-

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tors. Using traps baited with pheromone, Aldrich and Cantelo (1999) collected adults and released their progeny into field plots of potatoes infested with Colorado potato beetle, and achieved significant reductions in defoliation over untreated control plots.

While it is possible to collect large numbers of adult spined soldier bugs using pheromone-baited traps (an average of 1775 females per year at one location) (Aldrich and Cantelo 1999), the period of time during which the spined soldier bugs are collected (early to mid-April in Beltsville, MD) is several weeks earlier than the period of emergence of the Colorado potato beetle. Thus, a method to store field-collected spined soldier bug adults that halts egg production until needed and at the same time maximizes fecundity when it is time to release the predators in the field would be beneficial.

The objective of this study was to determine the effects of temperature, photoperiod, and feeding on the survivorship and fecundity of field-collected adult spined soldier bugs over a storage period of 5 wks, which is a likely time interval over which the predators would have to be stored prior to augmentative release against the Colorado potato beetle in Maryland.

Materials and Methods

Adult *P. maculiventris* used in this experiment were collected from 12 to 16 April 2003 at the Beltsville Agricultural Research Center, Beltsville, MD (UTM 342300E, 4318800N to 332300E, 4322200N, zone 18, NAD27). Fifty plastic "Aldrich" traps (Aldrich and Cantelo 1999) were positioned at a height of 1.5 m on vegetation along

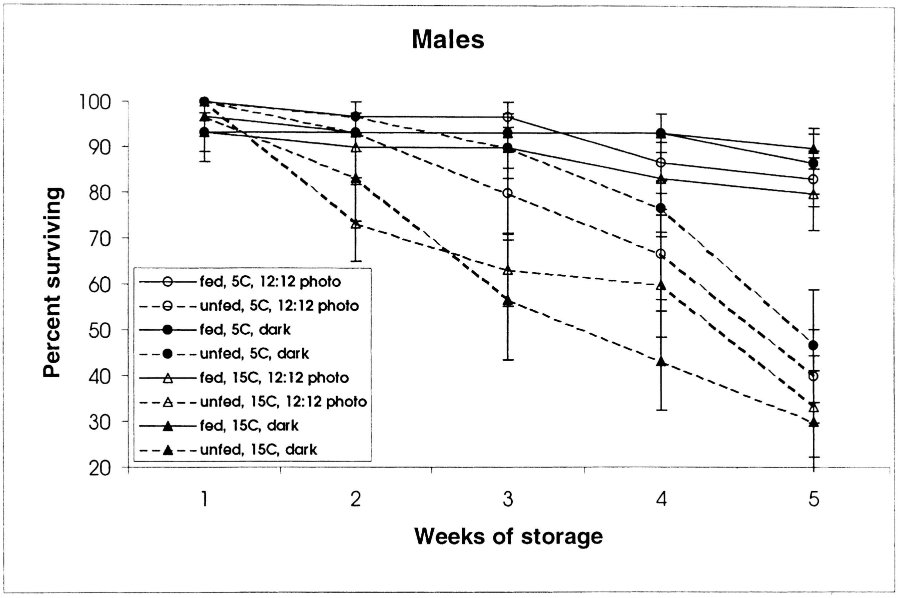

Fig. 1. Percent survivorship (mean ± SE) of six groups of five male *P. maculiventris* during storage at different temperature and photoperiod, with or without food.

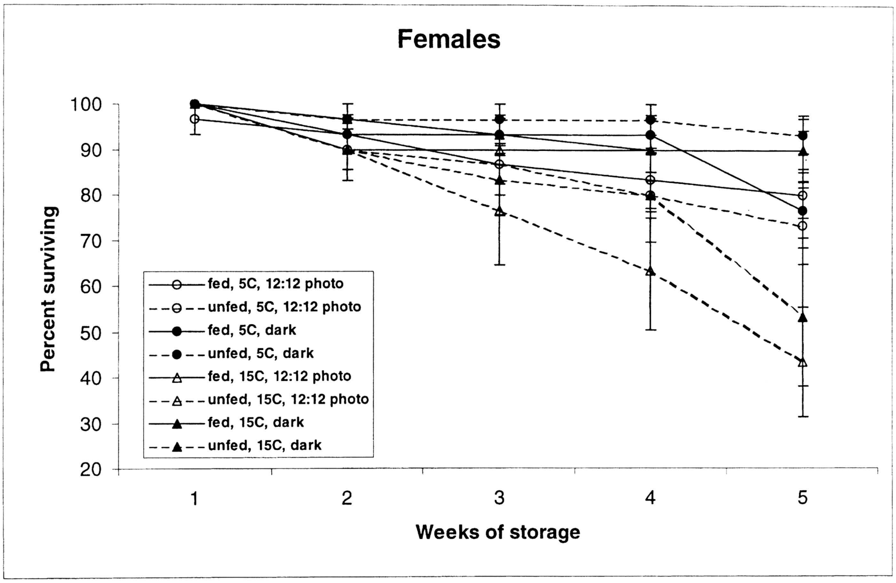

Fig. 2. Percent survivorship (mean ± SE) of six groups of five female *P. maculiventris* during storage at different temperature and photoperiod, with or without food.

roads at intervals of about 20 m and baited every 2 to 4 days with a blend of (*E*)-2-hexenal, α-terpineol, and benzyl alcohol (Aldrich et al. 1984, Aldrich 1998). Adults were removed every day and held in cages under ambient laboratory conditions.

On 18 April, adults were placed in groups of 5 males and 5 females in 480-ml paper containers. Each container was provisioned with distilled water in a 4-ml vial plugged with cotton. All combinations of the following three factors were tested: (1) temperature (5 or 15 ± 2°C); (2) fed vs unfed; and (3) 12:12 (L:D) photoperiod (to approximate the photoperiod that occurs at Beltsville, MD, during the time that the spined soldier bugs are trapped) or constant darkness. Six replicate containers were set up for each treatment combination (48 containers total). For the predators receiving food, containers were provisioned with three organically-grown string beans *Phaseolus vulgaris* L. and three mealworm, *Tenebrio molitor* L., larvae or pupae. Fresh water, beans, and mealworms were provided each week of the test. Fed insects kept at 5°C were warmed to room temperature every 2 to 3 days for 4 h to allow them to feed. All containers were placed in growth chambers set at the appropriate temperature and photoperiod. Mortality and number of eggs produced per container were recorded each week.

After 5 wks (on 21 May) the males were discarded, and all surviving females were placed in 480-ml paper containers noted above and provisioned with vials containing distilled water, three string beans, and 10 second-instar Colorado potato beetle larvae. Fresh food and water were added to the containers each week. All containers were kept in a growth chamber at 26 ± 2°C, 65 ± 5% RH, and 12:12 (L:D) photoperiod. There were five to six replicates of each of the treatment combinations. Depending on

Table 1. Fecundity of female *P. maculiventris* during and after storage at different temperature and photoperiod, with or without food

Temperature (°C)	Food	Photoperiod	Eggs/female produced in storage*	Eggs/ female after storage*	Nymphs/ female after storage*	Nymphs/ female originally collected**
5	No	L:D	0	12.5 ± 5.3	1.1 ± 0.6	0.5
			(n = 30)	(n = 12)	(n = 12)	(n = 30)
5	No	Dark	0	16.1 ± 6.5	4.6 ± 2.5	2.5
			(n = 30)	(n = 15)	(n = 15)	(n = 30)
5	Yes	L:D	1.6 ± 1.6	23.5 ± 3.4	15.8 ± 2.2	14.8
			(n = 30)	(n = 28)	(n = 28)	(n = 30)
5	Yes	Dark	0	34.8 ± 3.9	14.5 ± 1.7	13.1
			(n = 30)	(n = 27)	(n = 27)	(n = 30)
15	No	L:D	0.8 ± 0.8	9.1 ± 2.9	2.4 ± 1.1	1.8
			(n = 30)	(n = 22)	(n = 22)	(n = 30)
15	No	Dark	1.4 ± 0.6	8.9 ± 2.4	0.9 ± 0.4	0.8
			(n = 30)	(n = 28)	(n = 28)	(n = 30)
15	Yes	L:D	3.4 ± 1.2	34.6 ± 3.6	12.1 ± 2.0	9.7
			(n = 30)	(n = 24)	(n = 24)	(n = 30)
15	Yes	Dark	8.3 ± 2.6	34.6 ± 4.6	14.9 ± 3.0	11.4
			(n = 30)	(n = 23)	(n = 23)	(n = 30)

* Values are mean ± SE; n = number of females.

** Values are calculated from the proportion of females surviving storage × the mean number of nymphs produced per surviving female; n = number of females originally collected.

mortality during the first part of the test, each container held from 1 to 5 (mean = 3.9) females. Female mortality and the number of eggs produced per container were recorded each week for 5 wks. All eggs were placed on filter paper in plastic Petri dishes in the growth chambers at 26 ± 2°C and 12:12 (L:D) photoperiod, and the number of nymphs hatching was recorded.

Adult survivorship and fecundity data were analyzed by analysis of variance (ANOVA) using the General Linear Model procedure of the SAS statistics package (SAS Institute 1996).

Results

Male survivorship after 5 wks (the end of the storage period) was 80 to 90% for fed insects and 30 to 47% for unfed insects (Fig. 1), with feeding being the only factor affecting survival (F = 52.2; df = 1,40; P = <0.0001). Female survivorship after 5 wks ranged from 43 to 93% (Fig. 2), with temperature × food interaction being significant (F = 15.8; df = 1,40; P = 0.0003). Further, the significant interaction resulted from reduced survivorship among unfed females at 15°C, but not at 5°C (Fig. 2). Survivorship among females stored at 15°C and those stored at 5°C with food was 77 to 93%.

The number of eggs produced under various storage conditions ranged from 0 to 8.3 per female (Table 1). After the females were stored for 5 wks and then warmed to 26°C, egg production ranged from 9.1 to 34.8 per female. Food was the only significant factor ($F = 49.4$; df = 1,38; $P = <0.0001$). The number of resulting nymphs ranged from 0.9 to 15.8 per female. Again, food was the only significant factor ($F = 78.5$; df = 1,38; $P = <0.0001$). Eighty percent of the eggs were produced during the first week after the females were removed from storage. Female mortality averaged 82% by the third week and by the fifth week all females were dead (Fig. 3).

Discussion

Based on the results of this experiment, presence or absence of feeding is the most significant determinant of both survivorship and fecundity. Temperature either had no effect, or interacted with feeding such that female survivorship was greatest at 5°C regardless of whether the insects were fed or not. Therefore, 5°C appears to be the best temperature for short-term storage of spined soldier bugs, which is convenient because household refrigerators generally are maintained at this temperature. Photoperiod does not appear to be important, so lighting conditions in refrigerators (constant dark unless the door is open) should be adequate. Feeding is important, so

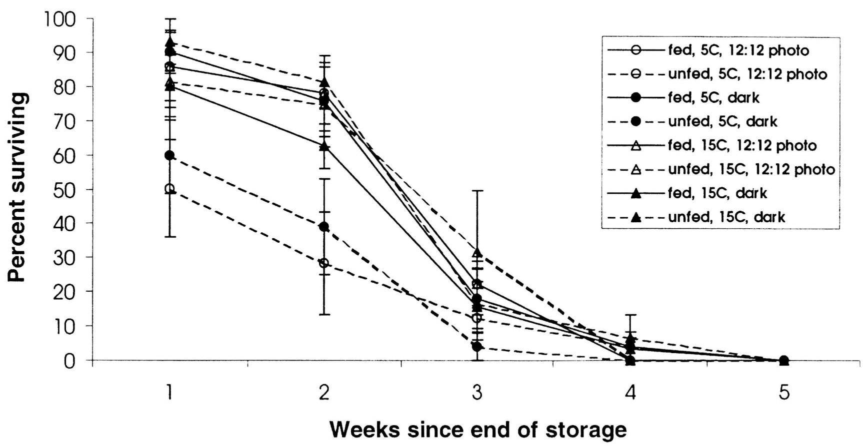

Fig. 3. Percent survivorship (mean ± SE) of five groups of from one to five female *P. maculiventris* after being stored for 5 wks at different temperature and photoperiod, with or without food.

spined soldier bugs will need to be provisioned with green beans and mealworms and removed from storage every 2 to 3 days so that they can warm up to feed. While the effects of low relative humidity (RH) were not tested in this study, potential adverse effects of low RH that may occur in a refrigerator may be mitigated by storing the spined soldier bug adults in a container with moist paper towels.

Fecundity under the most optimal combination of conditions tested was relativley low (14 nymphs per female originally collected). This average fecundity value is based on the number of females at the beginning of the storage period, so females that died prior to oviposition are included in the average. Spined soldier bug females have been reported to oviposit 200 or more eggs (Hough-Goldstein and McPherson 1996, and references therein). Therefore, the fecundity values from stored females in this study represent a substantial reduction in fecundity from that which would be expected for healthy females whose reproduction is not delayed artificially. For small plantings of potatoes, it might be possible to offset reduced fecundity by the collection of large numbers of wild females. However, it appears that spined soldier bug amplification by this method may be limited by the low fecundity of stored females and may not be appropriate beyond small potato plantings such as occur in gardens and small specialty farming operations.

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