Cold Tolerance of Hickory Shuckworm (Lepidoptera: Tortricidae) Larvae and Associated Parasites[1]

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ABSTRACT Hickory shuckworm larvae, *Cydia caryana* (Fitch), in pecan shucks, were killed by extended periods of freezing temperature. While storage at -7°C killed 88% of larvae after 32 days of exposure, -18°C killed 85% after only 1 day and 100% by 8 to 16 days of exposure. Larvae exposed to cold temperatures prior to -18°C exposure appeared to possess enhanced cold resistance but were still killed after 32 days of exposure. Survival of the ichneumonid parasite, *Calliephialtes grapholithae* (Cresson), which comprised 92% of the total of all parasites emerging from pecan shucks, was not detectably affected by exposure to cooling (3-5°C) for up to 5 wks. Thereafter, when emergence began to decrease, about half of the parasites in the extended cooling treatment were viable for at least 10 wks. Conversely, 3 other parasites *Phanerotoma fasciata* Provancher (Braconidae), *Macrocentrus instabilis* Muesebeck (Braconidae), and *Lixophaga mediocris* Aldrich (Tachinidae), comprised the remaining 8% of total parasite emergence and survival was severely affected by extended cooling (3-5°C).

KEY WORDS Hickory shuckworm, *Cydia caryana*, cold tolerance

The hickory shuckworm, *Cydia caryana* (Fitch), is a pest of pecan [*Carya illinonensis* (Wang) K. Koch] orchards from west Texas to the Atlantic Coast (Todd 1967). It overwinters as a larva in the previous year's shucks with adults emerging in early spring at, or about, bud break. This spring population usually causes little injury to nuts; however, larvae can attack and feed on the developing kernel and cause the nut to abort. Thus, heavy infestations can substantially reduce yields (Phillips et al. 1964). The larvae feed in shuck tissues surrounding the nuts after shell hardening and sever the vascular system, thus nuts are poorly filled and ripening is delayed (Adair 1930). Hickory shuckworm infestations also cause discoloration of the shell surface, thus lowering nut value (Gill 1924).

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Unlike the southeastern sector of the U.S. Pecan Belt, the southwestern sector is largely free of this pest. Because Southwest-based shellers often need to import in-shell nuts from shuckworm-infested regions, there is potential for introducing these pests into the southwestern sector. Shellers and agricultural departments of western states, therefore, need information on methods of killing shuckworms that might be contained within inshell nuts. One such method is that of killing larvae by exposure to cold temperatures. Additionally, biological control strategies for shuckworm could potentially benefit from methods to control the emergence of shuckworm parasites. This communication reports the influence of different temperatures and exposure periods on survival of hickory shuckworm larvae and on some of their natural parasites.

Materials and Methods

Effect of Temperature on Survival of Hickory Shuckworm Larvae. Pecan nuts with attached shucks were collected from unsprayed shuckworm infested trees of mixed cultivars during October and November 1992. Fifty nuts were held in organdy bags and stored at either -18°C, -7°C, or +22°C for 1, 2, 4, 8, 16, and 32 days. Larval survival was then determined for each treatment. The experimental design was a randomized block with 4 blocks, 3 treatment temperatures as main plots, and 6 exposure periods (or split-plots) within the main plots. Data were analyzed by SAS-GLM (SAS Institute 1988) methods to determine main and interactive effects. Significant treatments ($P \leq 0.05$) were then fitted with a response equation to define the functional relationship between shuckworm survival and duration of exposure to the temperature treatments.

Effect of Pre-Conditioning Temperatures on Cold Tolerance of Hickory Shuckworm Larvae. Shuckworm-infested pecan shucks (approximately 500 kg) were collected from a commercial orchard (Valdosta, GA) after harvest (November) and evaluated to determine if temperature preconditioning influences larvae tolerance to cold. These shucks were stored at either 22°C or -4°C for 8 days prior to exposure to -18°C. The treatments were: (1) pre-conditioning at 22°C and then stored at -18°C; (2) pre-conditioning at -4°C and stored at -18°C; (3) pre-conditioning at 22°C and stored at 22°C; and (4) pre-conditioning at -4°C and stored at 22°C. The experimental design was a factorial in a randomized complete block consisting of 4 treatments, 5 blocks, and 5 exposure periods (2, 4, 8, 16 and 32 days). The experimental unit of each treatment consisted of 1 kg of shucks. Larval survival was analyzed by ANOVA and by Tukey's HSD test (SAS Institute 1988).

Effect of Refrigeration on Delay of Hickory Shuckworm Parasite Emergence. The influence of cold temperatures on the delaying and survival of shuckworm parasites was evaluated by storing infested shucks at 3-5°C for several weeks before being placed in a warmer temperature which allowed for emergence of parasites. Pecan shucks, infested with hickory shuckworm larvae, were collected from unsprayed 10-year-old 'Cheyenne' trees (January 1993), placed in small burlap bags (1200 quarters per bag), and stored at 4°C on February 12. The experimental design consisted of 4 replicates (randomized complete block), 10 temperature duration periods (weekly from 1 to 10 weeks), plus a check where shucks were left in the field environment. Parasite emergence was monitored by removing shucks from 4°C at the appropriate weekly intervals and placed in black plastic buckets equipped with insect collecting traps where emerging hickory shuckworm moths and parasites were trapped and then identified.

Results

Effects of Temperature on Survival of Hickory Shuckworm Larvae. Survival of shuckworm larvae declined as exposure temperature declined and as length of exposure increased (Fig. 1). There was a strong 'temperature and days of exposure' interaction. For example, there was no detectable mortality of larvae stored at 22°C, whereas survival rapidly diminished when exposed to lower temperatures. Larval survival diminished in a sigmoidal manner with increasing time of low temperature exposure. The sigmoidal response curve (r^2 = 0.99) for larvae exposed to -7°C was such that mortality (% mortality per day of exposure) substantially diminished as exposure (52% surviving) increased; however, 12% still survived after 32 days of exposure. Therefore, a small percentage of the larval population was resistant to moderately cold temperatures by this stage of development. Conversely, only 17% of larvae survived after 24 hours of exposure to -18°C. All had died by between 8 (1% surviving) and 16 days of exposure to -18°C; hence, the shuckworm larvae at this stage of development (i.e., late November) were not capable of withstanding prolonged exposure to -18°C temperatures.

Effect of Pre-conditioning Cold Temperature on Hickory Shuckworm Larvae. ANOVA results of these data indicate that the -4°C preconditioning temperature did not adversely influence ($P > 0.05$) subsequent larval survival at 22°C (analysis not presented). When larvae were exposed to -18°C, all larvae were killed after 32 days of exposure regardless of whether larvae were exposed to either 22 or -4°C; however, at 8 days of exposure larvae pre-exposed to -4°C before exposure to -18°C survived better than those not receiving the cold pretreatment (Fig. 2). It is noteworthy that larvae exposed to 22°C and then to -18°C in this study survived far better for the first 1-16 days of exposure to the same temperature environment described in the first study (Fig. 1 vs Fig. 2). Although these 2 studies were done in 2 separate years, and because larvae were likely exposed to cold temperatures for longer periods in the second study (late November vs late October / early December), the increased tolerance to -18°C exposure suggests that ambient temperatures in the orchard influences larval tolerance to cold temperature.

Effect of Refrigeration for Delay in Hickory Shuckworm Parasite Emergence. Four species of shuckworm parasites emerged from pecan shucks in this tests (Table 1). Eighty-nine percent of the shuckworm larvae were parasitized, with 92% (700) being *Calliephialtes grapholithae* (Cresson) (Icheumonidae), 4% (28) *Phanerotoma fasciata* Provancher (Brachonidae), 1% (9) *Macrocentrus instabilis* Muesebeck (Braconidae), and 3% (24) *Lixophaga mediocris* Aldrich (Tachinidae).

Calliephialtes grapholithae survived well at 4°C for up to about 6 wks of exposure (Table 1), but diminished after 7 to 10 wks of exposure with about 50% of these parasites failing to emerge. Survival of the parasites, *P. fasciata* and *L. mediocris,* appears to have been greatly reduced by exposure to 4°C for as little

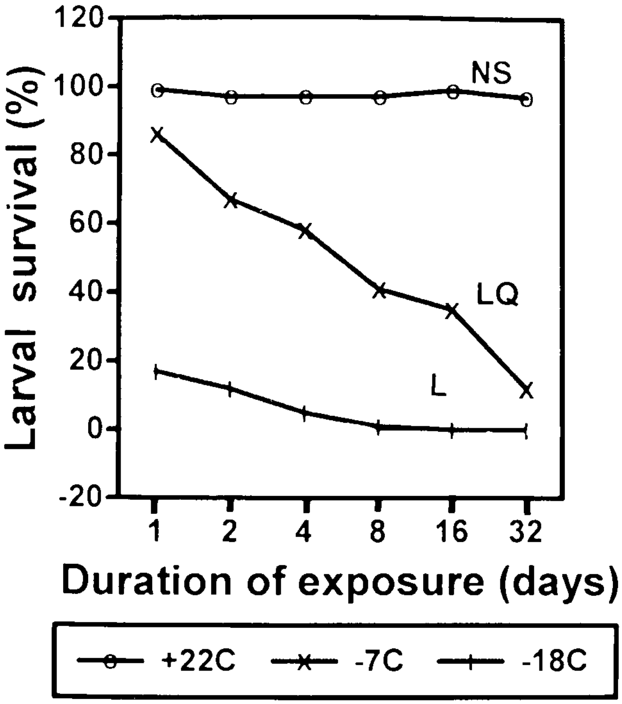

Fig. 1. Survival of hickory shuckworm larvae after exposure to different temperatures for different periods of time. Regression analysis revealed a lack of statistical significance ($P \leq 0.05$; NS) in larval survival when exposed to 22°C but linear/quadratic (LQ) and linear (L) declines at -7°C and -18°C, respectively. The best-fit sigmoidal response equation for storage at -7°C was:
$y = 14.5 + 5881/\{1 + \exp[-(x + 30.6)/-7.17]\}$, $r^2 = 0.99$, where y = percentage of larval survival and x = days of exposure to -7°C. The response equation for storage at -18°C was: $y = 6.7 - 68/\{1 + \exp[-(x + 1.51)/2.25]\}$, $r^2 = 0.99$.

as 1 wk. The numbers of *M. instabilis* were so low in the check so as to preclude definitive conclusions about their tolerance to cold storage, although the data indicate that there may be substantial survival for up to 5 wks of 4°C storage.

Discussion

These data indicate that hickory shuckworm infested nuts will most likely be free of living larvae after exposure of nuts to -18°C for between 8 and 16 days;

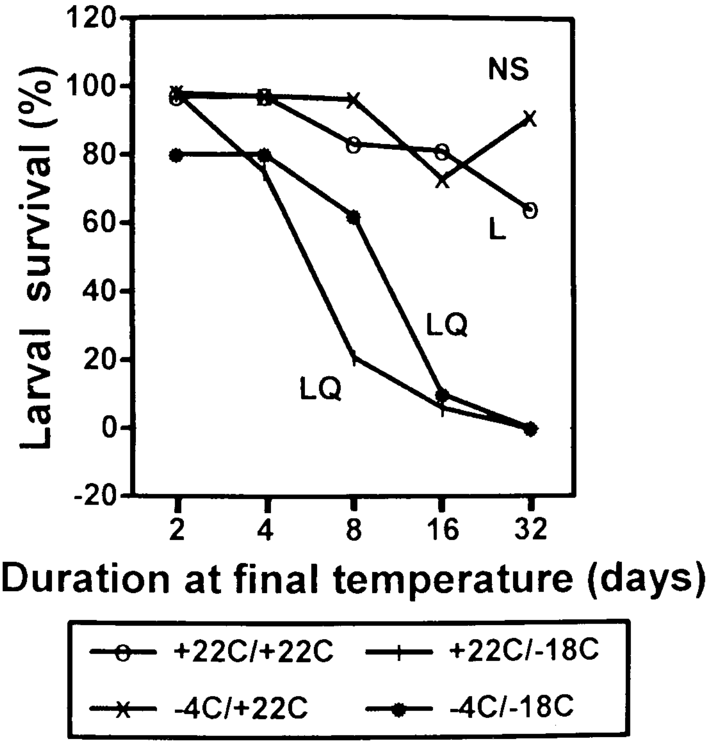

Fig. 2. Survival of hickory shuckworm larvae after exposure to cold temperatures for different durations after prior cold exposure. Larvae were first exposed to either +22°C or -4°C prior to extended exposure at either +22°C or -18°C for up to 32 days. Letters represent linear (L) or quadratic (Q) effects or nonsignificance (NS) at ($P \leq 0.05$).

however, temperature preconditions and physiological age of larvae are likely to influence cold tolerance. Shorter exposure periods or warmer exposure temperature are likely to allow for survival of a few shuckworm larvae, especially if nuts were left in the field environment late in the year and larvae were exposed to colder temperatures as winter approaches and/or progresses. An alternate means of killing larvae is that of heat treatment (Payne and Wells 1974); although this is often a liability insomuch that it substantially reduces nut quality (and nut value) by darkening the seed coat. If cold treatment is relied upon to kill shuckworm larvae, caution should therefore be exercised to treat nuts as soon after nut ripening as is practical so as to insure that cold adapted larvae do not develop and therefore survive the -18°C freezing.

These data also indicate that the emergence of viable hickory shuckworm parasites can be manipulated to produce emergence periods compatible with

Table 1. Emergence of hickory shuckworm (*Cydia caryana*) larvae parasites after storage of different durations at 4°C.

Cold storage (weeks)	Number of parasites emerging from pecan shucks				Emergence *Cydia caryana*
	Calliephialtes grapholithae	*Phanerotoma fasciata*	*Macrocentrus instabilis*	*Lixophaga mediocris*	
0*	78	23	1	11	23
1**	60	0	2	1	5
2	86	2	1	4	21
3	86	0	1	3	9
4	80	0	2	2	8
5	96	1	2	1	9
6	63	1	0	1	2
7	33	1	0	1	7
8	45	0	0	0	7
9	44	0	0	0	0
10	29	0	0	0	1

* These shucks were placed in the field on this date to allow for natural emergence of parasites and adult moths.
** Removed March 30.

growers needs for parasites to suppress hickory shuckworm populations. This study indicates that different species of the hickory shuckworm parasites are likely to exhibit differential tolerance to cold; hence, storage protocol would be expected to vary depending upon the particular parasite. The primary parasite, *C. grapholithae,* seems to be reasonably tolerant to cold storage, thus allowing it to be held long enough so that its emergence can be timed to coincide with hickory shuckworm development so as to suppress population build-up in orchards.

References Cited

Adair, H. S. 1930. The hickory or pecan shuckworm. Mississippi State Plant Board 4: 1-3.

Gill, J. B. 1924. Important pecan insects and their control. U. S. Dept. Agric. Farmer's Bull. 1364: 7-11.

Payne, J. A. and J. M. Wells. 1974. Postharvest control of the hickory shuckworm and the pecan weevil in inshell pecans. Proc. Annual Convention of Western Pecan Growers Assoc. 8: 29-35.

Phillips, A. M., J. R. Large and J. R. Cole. 1964. Insects and diseases of the pecan in Florida. Univ. of Florida Agric. Exp. Sta. Bull. 619A: 5-7.

SAS Institute. 1988. SAS/STAT User's Guide. Release 6.03. SAS Institute, Cary, NC.

Todd, L. 1967. A spring emergence study of the hickory shuckworm, *Laspeyresia caryana*. Proc. Texas Pecan Growers Assoc. 80-85.