

VIABILITY AND DEVELOPMENTAL THERMAL UNITS FOR *AGROTIS IPSILON* AND *SPODOPTERA LITTORALIS* PUPAE STORED AT COLD CONDITIONS

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Abstract

Groups of pupae aged 1, 2, 4 and 6 days of *Spodoptera littoralis* and *Agrotis ipsilon* were continuously stored at three cold conditions of 5, 10, and $15\pm 0.5^{\circ}\text{C}$ to clarify their viability and thermal units needed for development until moth emergence compared with pupae kept at $27\pm 0.5^{\circ}\text{C}$ till moth emergence were also carried out.

The obtained results manifested that, *Agrotis* pupae were more tolerant for the tested conditions than *Spodoptera* pupae, in the same time, younger pupae of both insects remained alive for longer periods than the older.

Agrotis pupae, all ages, could be stored alive for 1-17 day according to the age and temperature. Also, more than 90% of *Spodoptera* pupae remained alive for 2-13 day at 10 and $15\pm 0.5^{\circ}\text{C}$.

The cold storage of pupae, in this research, inhibited completely the emergence of *Spodoptera* moths although the gained degree day units (149.14) exceeded those needed for 100% moth emergence in the check (132.30 units). In the same time, these cold conditions depressed sharply the emergence of *Agrotis* moths (15.0-26.7%) which not began before 12 day at $15\pm 0.5^{\circ}\text{C}$ with low thermal units (135.4-154.8). Degree day units needed for emerging 83.6% of the check moths were 199.2 units.

INTRODUCTION

Many of insect pests, as *S. littoralis* and *A. ipsilon*, are major destructive for numerous field crops. So, numerous investigations have been carried out on both insects to control them successfully. These researches, to be achieved, need big numbers of certain stages at certain ages for direct use or storing until needed. Cold conditions are successfully used for storing different insects as *S. littoralis*, *A. ipsilon*, *S. cretica* and *O. nubilalis* by Kirolos and Mostafa (1980), Lutfallah and Awadallah (1984) and Abdel-Samea *et al.* (1998). Also, parasitized eggs were successfully stored by Fevzri& Adem (2001) and Ventura *et al.* (2002) and storing pupae by Salem (2006).

The present investigation aimed to clarify possibility of storing, different ages, of *S. littoralis* and *A. ipsilon* pupae at different cold conditions as long as possible in addition to calculate degree day units required for development and moths emergence.

MATERIALS AND METHODS

The present research aimed to clarify effects of three temperature degrees, 5, 10 and $15\pm 0.5^{\circ}\text{C}$ on viability of *S. littoralis* and *A. ipsilon* pupae aged 1, 2, 4 and 6 day in addition to calculate their thermal units needed for development and producing moths.

A culture of each insect was maintained in the laboratory to gain healthy and newly pupae which were kept under $27\pm 0.5^{\circ}\text{C}$ until be used.

Three groups, each 50 of one day old pupae, were separately kept at the three mentioned low temperatures. By the same way, another groups of pupae aged 2, 4, and 6 day of both insect species were kept at the same low temperatures. In the same time, a group of 50 newly pupae were continuously kept at $27+0.5^{\circ}\text{C}$ (as a check) until moths emergence. The pupae of each group were kept in a suitable plastic cup, provided with a piece of cotton wool wet with water as a source of humidity, covered with a pin notched cover.

All pupae received a daily inspection to record number of the survivors as well as number of the emerged moths.

Accumulative degree day units, in this work, were also calculated using zero pupal development values as previously reported by Abdin and Eissa (2001) as 10.4°C for *A. ipsilon* and 12.3°C for *S. littoralis* (Hassan, 2005).

RESULTS and DISCUSSION

Data presented in Table (1) indicate that, regardless of age, *S. littoralis* pupae survived alive for long periods as the temperature was increased, 6-12, 15-35 and 23-27 day at 5, 10 and $15\pm 0.5^{\circ}\text{C}$, respectively. Mortality percentages with increased gradually with increasing time with storage until reached 100% according to the pupal age. These results are in agreement with that of Jarry and Tremblay (1989) who showed that, as the duration of cold storage increases, living activity decreases and eventually stops. In this respect, Okinel *et al.* (1996) found that, the percentage of *Diadegma insulare* adult emerging from cocoons declined staidly with time spent in storage at 4°C . Abdel-Samea *et al.* (1998) also pointed to that, *Ostrinia nubillis* stages affected negatively by the temperature which is considered an important factor for development.

Data in the same table revealed that, a big portion (43.9-71.8%) of *S. littoralis* pupae died after 2 day exposing to $5\pm 0.5^{\circ}\text{C}$. The youngest pupae were relatively more tolerant for this cooling condition than the older. The pupae stored at $10\pm 0.5^{\circ}\text{C}$ were more viable since 80.0-96.9% of 1-4 day old pupae survived for 8 days. On the

other hand, the pupae aged more than 4 day were more sensitive, only 54.8% remained alive. All population, eventually, died through the different periods according to their ages, 35, 33, 25 and 15 days for 1, 2, 4 and 6 day ages, respectively. Keeping *Spodoptera* pupae, all ages, of this species at $15\pm 0.5^{\circ}\text{C}$ allowed 91.2-97.4% to be alive for the same mentioned period (8 d), in the same time, about 90.0% of 1 and 4 day old pupae alived for 13 day. The majority of pupae stored at this temperature died through 27 d with no moth emergence, Table (1). Table (3) Indicates that all check pupae, of *S. littoralis*, produced normal moths after 9.0 day as recorded by Isa & Khedr (1974) and Abdel- Samea *et. al.*, (2006), respectively.

The *Spodoptera* pupae kept below 12.3°C (the developmental threshold), i.e. at 5 or 10°C , not gained any thermal units except 14.66-87.96 degree days were gained at $27\pm 0.5^{\circ}\text{C}$ before cooling, Table (1). Keeping at $15\pm 0.5^{\circ}\text{C}$, although the accumulative thermal units reached 149.1, no moths were observed at the time in which the check pupae initiated producing moths (53.3 %) with 117.6 units only after 8 day and terminated the emergence (100 %) on the ninth day with 132.3 units as shown in Table (3).

Concerning *Agrotis* pupae Table (2) revealed that, they tolerated clearly the tested cold conditions more than those of *Spodoptera* species since they remained alive for 19-27 day at $5\pm 0.5^{\circ}\text{C}$ compared with 6-12 day only, in the later species, according to the age. Also, more than 70.0 % of one day old *Agrotis* pupae, survived for 13 day at this temperature while about 43.0-70.0 % of the *Spodoptera* pupae were killed after 2 day only. These results are in agreement with findings of Abdin and Eissa (2001) and Hassan (2005) when they reported 10.4 and 12.3°C as zero developments for *Agrotis* and *Spodoptera*, respectively i.e. the prior insect is more tolerant for cold conditions.

Data in the same table also pointed to that, percentages of living *Agrotis* pupae correlated positively, as in *Spodoptera*, with the temperature, this result coincide with that recorded by Salem (2006). All *Agrotis* pupae stored at 5 or $10\pm 0.5^{\circ}\text{C}$ failed, as in *Spodoptera*, to produce moths. Thus, due to the, extended exposure to temperatures below developmental thresholds, the pupae eventually died.

Storing at $15\pm 0.5^{\circ}\text{C}$, about of 15.0 and 26.7 % of 4 and 6 day old *Agrotis* pupae succeeded to produce moths with 135.4 and 154.8 degree days, respectively, Table (2). Moth emergence at $27\pm 0.5^{\circ}\text{C}$ initiated with 7.3% after 9 day with 149.4 thermal units and reached, a maximum of 83.6% with 199.2 units, after three days Table (3). In this respect, Abdin and Eissa (2001) recorded that 147.12 units were needed for completing the pupal development at 27°C .

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A general view for all previous data in tables (1-4) reveals that, *Agrotis* pupae could be stored alive (100 %), at any of the tested cold regimes, for 1-17 day according to their age. Also, more than 90.0% of *Spodoptera* pupae could be alive for 2-13 day at 10 and 15±0.5° C. Storing of *Agrotis* pupae at 15±0.5°C, delayed and, in the same time, sharply decreased the emergence of adults, 15.0 and 26.7 % moths only were obtained from 4 and 6 day old pupae with 135.4 and 154.8 thermal units after 15 and 12 day respectively. No moths were gained after storing the all ages of *Spodoptera* pupae at all tested cold regimes.

Table 1. Percentages of alive *Spodoptera* pupae with different ages (days), after storing at different low temperature degrees.

Storing period (day)	5 ± 0.5° C and ages				10 ± 0.5° C and ages				15 ± 0.5° C and ages			
	1	2	4	6 days	1	2	4	6 days	1	2	4	6 days
1	84.6	66.7	75.9	79.7	100.0	100.0	100.0	95.9	100.0 (17.32)	100.0 (31.98)	100.0 (61.30)	100.0 (90.62)
2	28.2	36.5	48.2	56.1	100.0	100.0	100.0	94.5	" (19.98)	" (34.64)	" (63.36)	" (93.28)
3	24.4	9.5	3.4	50.3	100.0	100.0	100.0	86.3	" (22.64)	" (37.30)	" (66.62)	" (95.94)
4	19.2	7.8	3.4	10.3	96.7	100.0	97.8	82.2	" (25.30)	" (39.96)	" (69.28)	" (98.60)
5	19.2	7.8	3.4	5.8	96.7	100.0	88.9	72.6	" (27.96)	" (42.62)	" (71.94)	" (101.26)
6	19.2	6.3	3.4	3.2	96.7	98.6	88.9	65.8	" (30.62)	" (45.28)	98.3 (74.60)	" (103.92)
7	19.2	6.3	1.9	0.0	96.7	97.1	86.7	56.2	" (33.28)	95.1 (47.94)	96.5 (77.26)	" (106.58)
8	17.9	4.8	0.0		93.3	96.9	80.0	54.8	96.4 (35.94)	91.2 (50.60)	" (79.92)	" (109.24)
9	11.5	4.8			85.0	95.7	77.8	52.1	" (38.60)	84.2 (53.26)	94.7 (82.58)	" (111.90)
10	7.7	0.0			85.0	91.3	77.8	45.2	" (41.26)	82.9 (55.92)	" (85.24)	92.3 (114.56)
11	7.7				85.0	88.4	77.8	39.7	" (43.92)	81.7 (58.58)	" (87.90)	88.5 (117.22)
12	3.9				85.0	88.4	77.8	28.8	" (46.58)	" (61.24)	93.0 (90.56)	75.6 (119.88)
13	0.0				85.0	88.4	77.8	23.3	92.9 (49.24)	75.6 (63.80)	91.2 (93.22)	" (122.54)
14					76.7	88.4	75.6	16.4	91.9 (51.90)	" (66.56)	" (95.88)	" (125.20)
15					76.5	85.5	64.4	8.2	82.1 (53.56)	63.5 (69.22)	86.0 (98.50)	71.8 (127.86)
17					76.5	85.5	64.4	0.0	64.3 (59.28)	50.0 (74.54)	79.0 (103.86)	47.4 (133.18)
19					70.0	78.3	46.7		55.4 (65.20)	30.5 (79.86)	63.2 (109.18)	30.8 (138.50)
21					66.7	76.8	37.8		37.5 (70.52)	23.2 (85.18)	29.8 (114.50)	14.1 (143.82)
23					66.7	69.6	13.3		23.2 (75.84)	2.4 (90.50)	8.8 (119.82)	1.3 (149.14)
25					58.3	60.9	6.7		14.3 (81.16)	0.0	0.0	0.0
27					41.7	40.6	0.0		7.9 (86.48)			
29 - 31					38.3 - 31.7	30.4 - 21.7			0.0			
33 - 35					15.4 - 6.3	12.4 - 0.0						
Total	(14.7)	(29.3)	(58.6)	(88.0)	(14.7)	(29.3)	(58.6)	(88.0)	(86.5)	(90.5)	(119.8)	(149.1)

Numbers between brackets indicate accumulative degree days units (DDU).

Table 2. Percentages of alive *Agrotis* pupae with different ages, after storing at different low temperature degrees.

Storing period (day)	5+0.5° C and ages				10+0.5° C and ages				15+0.5° C and ages			
	1	2	4	6 days	1	2	4	6 days	1	2	4	6 days
1	100.0	100.0	100.0	99.0	100.0	100.0	100.0	100.0	100.0 (21.1)	100.0 (37.8)	100.0 (71.0)	100.0 (104.2)
2	100.0	97.0	98.6	82.7	100.0	100.0	100.0	100.0	100.0 (25.8)	100.0 (42.4)	100.0 (75.60)	100.0 (108.8)
3	100.0	97.0	98.6	74.5	100.0	100.0	100.0	100.0	100.0 (30.4)	100.0 (47.0)	100.0 (80.2)	100.0 (113.4)
4	97.8	92.4	95.8	64.5	96.6	100.0	100.0	96.6	100.0 (35.0)	86.0 (51.6)	51.7 (84.8)	46.6 (118.0)
5	97.8	92.4	94.3	62.7	96.6	100.0	100.0	80.0	100.0 (39.6)	82.0 (56.2)	46.7 (89.4)	46.6 (122.6)
6	93.3	92.4	88.6	60.0	96.6	100.0	100.0	75.0	100.0 (44.2)	78.0 (60.8)	45.0 (94.0)	45.0 (127.2)
7	93.3	90.9	87.1	57.2	96.6	100.0	100.0	68.3	90.0 (48.8)	72.0 (65.4)	40.0 (98.6)	41.7 (131.8)
8	86.7	83.3	81.4	50.0	96.6	100.0	100.0	55.0	86.2 (53.4)	62.0 (70.0)	31.6 (103.2)	40.0 (136.4)
9	86.7	75.8	75.7	44.5	96.6	100.0	100.0	55.0	81.2 (58.0)	62.0 (74.6)	25.0 (107.8)	40.0 (141.0)
10	82.2	69.7	67.2	42.7	96.6	100.0	100.0	55.0	76.2 (62.6)	58.0 (79.2)	16.6 (112.4)	36.7 (145.6)
11	80.0	62.1	54.3	35.4	90.0	100.0	100.0	35.0	76.2 (67.2)	48.0 (83.8)	15.0 (117.0)	26.7 (150.2)
12	73.3	52.4	45.8	32.7	76.7	100.0	100.0	26.7	75.0 (71.8)	42.0 (88.4)	15.0 (121.6)	26.7* (154.8)
13	73.3	34.8	44.3	30.0	75.0	100.0	100.0	23.3	75.0 (76.4)	28.0 (93.0)	15.0 (126.2)	
15	62.2	33.3	31.5	20.0	66.7	100.0	93.2	10.0	71.3 (85.6)	16.0 (102.2)	15.0* (135.4)	
17	55.6	25.7	24.3	11.8	63.3	100.0	81.7	0.0	65.0 (94.8)	14.0 (111.4)		
19	53.3	21.2	11.4	2.8	61.7	93.3	63.3		61.2 (104.0)	4.0 (120.6)		
21	42.2	13.6	1.4	0.0	58.3	93.3	48.4		22.5 (113.2)	0.0		
23	33.3	7.5	0.0		53.3	91.7	38.3		8.7 (122.4)			
25	17.8	0.0			51.7	88.3	25.0		0.0			
27	6.7				51.7	88.3	18.3					
29-31	0.0				43.3- 26.7	55.0- 28.3	8.3- 1.7					
33-35					10.0- 1.7	15.0-5.4	0.0					
37					0.0	0.0						
Total	(16.6)	(33.2)	(66.4)	(99.6)	(16.6)	(33.2)	(66.4)	(99.6)	(122.4)	(120.6)	(135.4)	(154.8)

* Moth emergence (%)

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Table 3. Percentages of alive *Spodoptera* and *Agrotis* pupae and accumulative degree days at 27±0.5 °C.

Insect	Alives (%)										
	1	2	3	4	5	6	7	8	9	10	12d
<i>Spodoptera</i> <i>a</i> <i>littoralis</i>	100.0	100.0	100.0	100.0	100.0	100.0	100.0	46.7	0.0		
	(14.7)	(29.4)	(44.1)	(58.8)	(73.5)	(88.2)	(102.9)	53.3*	100*		
<i>Agrotis</i> <i>ipilon</i>	100.0	100.0	100.0	100.0	100.0	100.0	100.0	96.4	85.5	18.2	0.0
	(16.6)	(33.2)	(49.8)	(66.4)	(83.0)	(99.6)	(116.2)	132.8	7.3*	67.3*	83.6*
								(132.8)	(149.4)	(166.0)	(199.2)

Table 4. Percentages of *Spodoptera* and *Agrotis* pupae, degree days and moth emergence (%) at 5, 10 and 15 ± 0.5 °C.

Species	± 0°.5° C	Alives (%)	DDU	Emerg. (%)
<i>Spodoptera</i> <i>littoralis</i>	5	66.0 - 84.0 (1)	--	0.0
			--	0.0
	10	95.0 - 100.0 (2-5)	--	0.0
		75.6 - 88.9 (4-21)	--	
	15	100.0 (4-7)	33.3 - 98.6	0.0
		91.2 - 98.3 (8-14)	49.2 - 114.6	
	71.8 - 88.5 (13-17)	53.6 - 127.9		
<i>Agrotis</i> <i>ipilon</i>	5	90.0 -100.0 (1-7)	--	0.0
		80.0 - 86.7 (2-11)	--	
	10	100.0 (3-17)	--	0.0
		90.0-96.6 (4-23)	--	
		75.0-83.3 (5-27)	--	
	15	100.0 (3-6)	44.2 -113.4	15.0 - 26.7
71.3-82.0 (4-15)		56.2 - 85.6		

Numbers between brackets represent lifespan in days.

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حيوية عذارى دودة ورق القطن (إسبودوبترا لتورالس) والدودة القارضة
 (أجروتس إبسيلون) واحتياجاتها الحرارية عند تخزينها على درجات حرارة منخفضة

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تم حفظ عذارى ذات اعمار مختلفة من دودة ورق القطن الكبرى والدودة القارضة على درجات حرارة ٥ ، ١٠ ، ١٥ ± ٠,٥ م لمعرفة مدى حيويتها واحتياجاتها الحرارية اللازمة لتطورها وانتاج فراشات - وكانت المقارنة بمجموعتين من عذارى كلتا الحشرتين حفظتا على درجة ٢٧ ± ٠,٥ م .

اوضحت الدراسة ان عذارى الدودة القارضة كانت اكثر تحملا لظروف التخزين ذات الحرارة المنخفضة عن عذارى دودة ورق القطن ، وان العذارى الأصغر عمرا فى الحشرتين كانت ايضا اكثر تحملا لهذه الظروف حيث ظلت حية لفترات اطول.

امكن حفظ عذارى الدودة القارضة لفترات تراوحت بين ١ ، ١٧ يوما حسب العمر ودرجة الحرارة ، كما ان اكثر من ٩٠ % من عذارى دودة ورق القطن قد عاشت ٢ - ١٣ يوما على درجتى حرارة ١٠ ، ١٥ ± ٠,٥ م .

نتج عن تخزين عذارى دودة ورق القطن عند درجات الحرارة الثلاثة المنخفضة فشل خروج اى فراشات منها بينما فى عذارى الدودة القارضة فقد ،مالم ها التخزين مدة الطور العذرى للفراشات والتي ظهرت بنسبة منخفضة (١٥,٠ - ٢٦,١ %) على درجتى حرارة ١٠ ، ١٥ ± ٠,٥ م فقط و باحتياج حرارى منخفض (٨٥,١٥٤ وحدة) مقارنة بـ ١٩٩,٢ وحدة لعذارى الكنترول والتي اعطت ٨٣,٦ % فراشات .