Article

A quantitative study on development, fecundity and mortality of beet armyworm, *Spodoptera exigua* (Hübner) (Lepidoptera: Noctuidae), infected by SeMNPV

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Abstract
Beet armyworm, *Spodoptera exigua* (Hübner), is an important pest for many crops. SeMNPV infected development, survival process, and population parameters of *S. exigua* were studied in present study. The results demonstated that relationship beween probit value of mortality (*y*) and the logarimic of SeMNPV concentration (*x*) followed the linear equation: y=0.455+0.9300x. At 27 ℃, the LC_{50} of the third-instar larvae of *S. exigua* was tested to be 77082 PIBs/ml. Pupa weight (*y*; mg) of *S. exigua* decreased significantly with the SeMNPV concentration (*x*; SeMNPV concentration (PIBs/ml)): y=106.038-1.1962 log(x) (r^2=0.915, p=0.044). Fecundity (*y*; eggs/female) of *S. exigua* decreased significantly with the SeMNPV concentration: y=690.523-28.5209 log(x) (r^2=0.997, p=0.001). Both net reproduction rate (R_0) and population trend index (I) decreased with the SeMNPV concentration (x): R_0=744.121-54.6707 log(x) (r^2=0.983, p=0.009); I=354.259-24.4705 log(x) (r^2=0.987, p=0.006).

Keywords *Spodoptera exigua*; SeMNPV; infection; development; survival; fecundity; pupa.

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1 Introduction

Beet armyworm, *Spodoptera exigua* (Hübner) (Lepidoptera: Noctuidae) feeds on 170 species and 35 families of plants, and injures a variety of vegetables, cotton, tobacco, corn, peanuts, and sugar beet, etc (Greenberg et al., 2001; Karimi-Malati et al., 2014).

S. exigua has generally five instars, sometimes six instars, of larvae stages (Ali and Gaylor, 1992). Early larvae of *S. exigua* injure host plants mainly in groups but they spread since the third instar larvae. Starting from the fourth instar, larvae's food intake increase. The fourth and fifth instar larvae comsume 80-90% of total food at the larvae stage. The older instar larvae pupate in the soil (Fey, 1978). Female moths can quickly lay eggs after mating. The female moth can lays 713±154 eggs for 4.8±1.5 days (Wakamura, 1990).

Ali and Gaylor (1992) exploited the effects of temperature and host plants on the development of *S. exigua*.

The results showed that between 15~36 ℃, its development had linear growth relationship, and a high temperature exceeding 36 ℃ could restrain its development. Food and nutrition has a great impact on the larval development and adult reproduction. Ali and Gaylor (1992) found that pupa weight closely related to nutrition. When feeding with artificial food, the body weight of *S. exigua* pupa was greater than that feeding with plant tissue.

SeMNPV (*Spodoptera exigua* nuclear polyhedrosis virus) is an important biological agent for *S. exigua*. Various studies on SeMNPV have been conducted in the past (Hunter and Hall, 1968; Vlak et al., 1981, 1982; Geletnter and Federiei, 1986; Li et al., 2006;).

The present study aims to explore SeMNPV infected development, survival process, and population parameters of *S. exigua*, in order to provide some quantative relationships for further research and applications.

2 Materials and Methods

2.1 Materials

S. exigua was collected from Guangzhou Institute of Vegetable. Indoor feeding with artificial formula and host plants was conducted (Dai et al., 2017).

Artificial formula: casein 2 g, soybean meal 10 g, yeast 4 g, wheat bran 6 g, sorbic acid 0.2 g, Nipagin 0.2 g, ascorbic acid 0.4 g, cholesterol 0.1 g, chloride 0.08 g, trace nutrients I 2500 IU , trace nutrients Ⅱ 1000 IU, micro-nutrients Ⅲ, micro-nutrients IV 0.5 mg, micro-nutrients V 3 mg, agar 1.6 g, water 100 m1.

Host plants: *Raphanus sativus* L., *Allium fistulosum*, *Lactuca sativa*, *Lactuca Sativa* L., were cultivated under natural conditions at experimental garden without any chemicals.

2.2 Methods

2.2.1 Rearing conditions

Insects were reared in artificial climate boxes with controlled temperatures, the temperature fluctuation was ± 1 ℃. Fluorescent controlled light was used. Light periodicity is L: D = 12:12, and relative humudity is 75% ~ 85%.

2.2.2 Disinfection measures

In order to prevent disease, climate boxes were disinfected two hours before experiments using ultraviolet light or vaporization of 10 ml of 36.5% solution of formaldehyde. Appliances (tubes, forceps, feeding kit, etc.) were disinfected 30 minutes using high-temperature autoclave sterilization pan. Experimental room was regularly disinfected using 0.2% of sodium hypochlorite disinfectant.

2.2.3 Feeding

2.2.3.1 Eggs disinfection: Before the eggs hatched, add the eggs in the 5% formaldehyde solution for disinfection for 15 mins, and then clean, dry them with pure water. After the counting, put into a circular plastic box (13 cm × 4 cm, each with 40 to 100 eggs), and thereafter count the number of hatching eggs.

2.2.3.2 Larvae culture: Early larvae are still fed in circular plastic boxes (13 cm × 4 cm), until the third instar larvae. Distribute larvae in two boxes for rearing until larvae nearly pupate. Transfer mature larvae to pupation boxes. Record larvae number, mortality, larval duration and pupation rate.

2.2.3.3 Adults: In the pre-pupae period, remove the pupae from the sand, and identify male and female. Emerged female and male moths were paired. Add every pair of moths into a glass with diameter of 7 cm and height of 10 cm, and add 15% of honey supplements in the glass. The daily egg mass took out of the glass, Calculate the number of laid eggs every day. Record life expectancy of adults and hatching rate of eggs.

2.2.4 Experimental method

Experiment was fixed at 27 ℃. Use host plants to rear *S. exigua* larvae, repeat the experiments two times.

Use four concentrations of SeMNPV, 5×10^3 PIB/ml, 2×10^4 PIB/ml, 5×10^4 PIB/ml, and 1×10^5 PIB/ml

to infect the third instar larvae, each dealing with 36 larvae. Repeat the experiments two times. The first record was made after infection, and record the number of died larvae for each virus treatment. Pupa weight, fecundity, and some population parameters were recorded or estimated.

3 Results and Discussion

3.1 LC_{50} of SeMNPV for the third instar larvae of *S. exigua*

The results demonstated that relationship beween probit value of mortality (*y*) and the logarimic of SeMNPV concentration (*x*) follows the linear equation (Fig. 1):

$y=0.455+0.9300x$

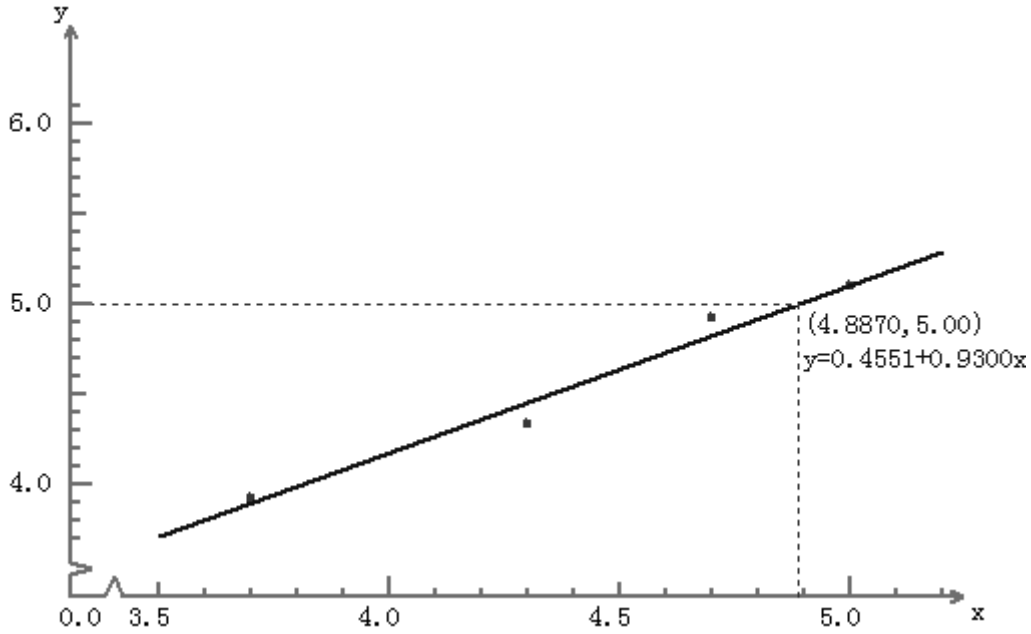

Fig. 1 Regression of the third instar larvae of *Spodoptera exigua* infected by SeMNPV.

LC values, derived fron the relationship above, are shown in Table 1. LC_{50} of the third larvae of *Spodoptera exigua* was 77082 PIBs/ml, higher than the LC_{50} value, 16623 PIBs/ml of Li et al. (2006), but lower than 262000 PIBs/ml of Zhang et al. (2001), and 103110 PIBs/ml of Zhang et al. (2004). SeMNPV sensitivity of host insects, the infection time and the different SeMNPV (strains, etc.) may have led to such differences (Li et al., 2006; Zhang et al., 2001; Zhang et al., 2004).

Table 1 LC of SeMNPV for the third instar larvae of *Spodoptera exigua*.

Lethal con. (PIBs/ml)	Log con.	LC (PIBs/ml)	SE	95% Confidence interval
LC_{30}	4.33	21272	0.0849	14496-31215
LC_{50}	4.89	77082	0.0849	52529-113110
LC_{70}	5.45	279314	0.0849	190345-409866
LC_{90}	6.26	1833571	0.0850	1249526-2690604

3.2 Effects of SeMNPV on the pupa weight and fecundity of *Spodoptera exigua*

According to Table 2, SeMPNV infection significantly influences the pupal weight of *S. exigua*. Compared with the control group, the pupae in infected group have produced more than 12% loss of body weight. The linear regression is

y=106.038-1.1962 log(x) r^2=0.915, p=0.044, n=4

where y: pupa weight (mg), x: SeMNPV concentration (PIBs/ml).

Table 3 reveals that fecundity of *S. exigua* reduces significantly with the SeMNPV concentration. The linear regression is

y=690.523-28.5209 log(x) r^2=0.997, p=0.001, n=4

where y: eggs/female, x: SeMNPV concentration (PIBs/ml).

Table 2 Pupa weight of *Spodoptera exigua* infected by different SeMNPV concentrations.

Infection con. (PIBs/ml)	Pupa weight (mg)	Sign. diff. (p=0.05)	F
Control	108.03±9.28	a	
5×10^3	95.55±5.33	b	
2×10^4	94.56±5.71	b	7.481
5×10^4	93.53±4.18	b	
1×10^5	91.76±8.41	b	

Table 3 Fecundity of *Spodoptera exigua* infected by different SEMNPV concentrations

Infection con. (PIBs/ml)	Fecundity (eggs/female)	Sign. diff. (p=0.05)	F
Control	607.00±106.65	a	
5×10^3	447.00±58.11	b	
2×10^4	410.22±114.51	b	4.670
5×10^4	379.55±99.78	b	
1×10^5	363.00±97.50	b	

3.3 Effects of SeMNPV on net reproduction rate and population trend index

According to Table 4, both net reproduction rate (R_0) and population trend index (I) decrease with the SeMNPV concentration. The linear regressions are as follows

R_0=744.121-54.6707 log (x), r^2=0.983, p=0.009, n=4
I=354.259-24.4705 log (x), r^2=0.987, p=0.006, n=4

Table 4 Net reproductive rate and population trend index of *Spodoptera exigua* infected by different SeMNPV concentrations

Infection con. (PIBs/ml)	CK	5×10^3	2×10^4	5×10^4	1×10^5
R_0	518.17	275.4	213.26	141.37	118.44
I	261.01	144.24	116.53	85.69	73.32

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