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Age-related Susceptibility of *Spodoptera litura* Larvae to Some Insecticides

담배거세미나방 유충의 영기별 약제 감수성

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ABSTRACT In the laboratory study, the toxicities of chlorpyrifos-methyl, chlorpyrifos, etofenprox, etofenprox+PAP and deltamethrin for different larval instars of *S. litura* decreased significantly as larvae aged. LC_{50} values for chlorpyrifos-methyl and chlorpyrifos increased significantly from 3rd instar larvae, while those for etofenprox+PAP and deltamethrin increased from 2nd instar larvae. In pot study, no significant differences in control efficacy were observed among each treated plots and over 90% control efficacy at 5 d after treatment was obtained in all of the treated plots, except treatment with deltamethrin. Therefore four insecticides excluding deltamethrin will be effective for controlling *S. litura*. However, it will be probably important to select appropriate insecticides and decide a proper time of treatment because the developmental stage is a significant factor in deciding insecticide efficacy because various developmental stages of the tobacco cutworm inhibit in fields.

KEY WORDS *Spodoptera litura*, Insecticide age-susceptibility

초 록 실내에서 담배거세미나방의 영기별 약제감수성을 조사한 결과 시험된 약제 모두 유충의 영기가 높아질수록 약제감수성은 낮았다. Chlorpyrifos-methyl과 chlorpyrifos의 독성은 3령부터, etofenprox+PAP와 deltamethrin은 2령부터 현저히 떨어졌다. 포트시험결과 deltamethrin을 제외한 4약제 모두 90% 이상의 방제가를 보여 담배거세미니방의 방제에 유용하게 사용될수 있을 것으로 생각된다. 하지만 야외에서 담배거세미나방은 전 영기가 혼재되어 있고 영기별 약제감수성이 다르기 때문에 적절한 약제선택은 물론 유충 발생초기에 약제를 살포하는 것이 중요하다.

검색어 담배거세미나방, 영기별 약제감수성

Tobacco cutworm, *Spodoptera litura* (Fabricius), is a common polyphagous pest of economically important vegetables and ornamental plants throughout tropical and subtropical Asia (Feakin 1973, Garad *et al.* 1984). It is known to attack 112 cultivated plant species (Moussa *et al.* 1960). In Korea, it has been believed that its occurrence was generally restricted to the southern part of this country, but it has become a problem in soybeans since late 1980 (Shin *et al.* 1987, Ahn and Lim 1991).

Recently this species has been expanding to the northern part of this country. Thus this insect could cause serious crop losses with feeding the leaves excessively (Anonymous 1992). Various stages of *S. litura* inhabit in the field during its active season. Of all stages, the last instar larva is economically most important because of its feeding damage on various crops and its high resistance to insecticides (Kondo 1987). The larva shows a rapid increase in body size with its molt, although its feeding is suspended in daytime; it feeds at night and hides in soil around the plant base. Due to its feeding behavior, this insect species is very difficult to be controlled and has rapidly developed resistance to insecticides.

Although none of the insecticide is registered for controlling *S. litura* in Korea, farmers primarily rely on the use of insecticides to reduce crop losses due to *S. litura*. However, farmers have appealed control failure

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of *S. litura* by insecticides because of widespread resistance to insecticides (Cho *et al.* 1995), which results from extensive use of insecticides. Therefore, the effective insecticides to control *S. litura* has been strongly required.

In the laboratory and pot study described herein, we assessed the effectiveness of some insecticides on different larval instars of the population of Spodoptera litura collected in Jinju.

MATERIALS AND METHODS

Insects

Field collections of the tobacco cutworm (*Spodoptera litura*) from Jinju (Gyeongsang Province) were brought into the laboratory and reared on the artificial diet modified from that reported by Lee and Boo (1993) and/or on Chinese cabbage leaves for two or three generations to ensure adequate numbers for testing. Adults were kept in cylindrical glass cages (ϕ 20×H10 cm) covered with the gauze and were provided with 10% sucrose water. Egg masses were collected and placed in plastic containers (25 by 15 by 10 cm) in which the larvae were reared. Some slices of artificial diet were supplied. All stages were kept at 25±1°C, 65±5% RH, and a photoperiod of 16: 8 (L: D) h.

Chemicals

All insecticides that purchased from the local formulator are as follows: chlopyrifos 25% wettable powder (WP); etofenprox+PAP 37% WP; chlopyrifos-methyl 25% emulsifiable concentrate (EC); deltamethrin 1% EC; etofenprox 10% EC.

Laboratory study

The toxicity of the insecticides against *S. litura* larvae was determined by leaf-disk dipping method as previously reported by Park *et al.* (1992). Various concentrations of each insecticide were prepared by diluting with running water. Chinese cabbage (*Brassica campestris napus* var. *peckinensis*) leaf-disks (ϕ5.5 cm) were dipped into these solutions for 30 s and allowed to dry. Newly molted instars (0-24 h old after ecdysis) at each larval stage were used. Treated groups consisted of 10 larvae at each concentration replicated three times with five concentrations for each insecticide. To avoid cannibalism, one larva was placed in one petri dish. Mortality was decided at 48 hrs after treatment. Data from all bioassay were corrected for control mortality with Abbott's (1925) formula. Larvae were considered dead if they were unable to move when prodded with a blunt probe and/or if they were shrunken more than two-thirds of body size before treatment. Results were analyzed using probit analysis (Raymond 1985).

Pot study

Pot tests were conducted with Chinese cabbages in the glasshouse. The pots were covered with coarse net to prevent escape of larvae. The insecticides were applied with hand sprayer equipped with one nozzle at 24 hrs after infestation of 20 third to fourth instar larvae per pot with three replicates, according to company recommendations for field application rates (per 1 liter); chlorpyrifos, 1 g/l: etofenprox+PAP, 1 g/l: chlorpyrifos-methyl, 1 ml/l; deltamethrin 0.65 ml/l; etofenprox, 1 ml/l. With examining the mean survival rates at 3 and 5 days after treatment, efficacy was expressed as control value using the formula, $CV = \{1\text{-}Ts/(Us\text{-}Ts)\} \times 100$, Ts = mean survival rate in the treated plot at 5 d after treatment; Us = mean survival rate in the untreated plot at 5 d after treatment. Mean survival rate (Sr) was calculated by the formula, $Sr = Ta/Tb \times 100$, Ta = number of larvae after treatment; Tb = number of larvae before treatment. Data were analyzed with Duncan's multiple reange test (SAS Institute 1986).

RESULTS AND DISCUSSION

Laboratory study

The toxicities of chlorpyrifos-methyl, chlorpyrifos, etofenprox, etofenprox+PAP, and deltamethrin for different larval instars of *S. litura* are given in Table 1. Of all the insecticides tested, chlorpyrifos-methyl was most toxic to the newly hatched larvae followed by chlorpyrifos, etofenprox, deltamethrin, and etofenprox+PAP. The susceptibility of *S. litura* larvae to all the

Table 1. Toxicity of some insecticides for different larval instars of *Spodoptera litura*

Instar and Insecticide		n	Slope±SE	LC$_{50}$^{a} (95% FL)	χ^2
1 st	Chlorpyrifos-methy	150	2.06±0.31	0.28(0.24-0.34)a	0.67
	Chlorpyrifos	150	1.08±0.19	0.30(0.22-0.40)a	1.07
	Etofenprox	150	1.51±0.21	0.93(0.64-1.18)b	0.33
	Etofenprox+PAP	150	1.37±0.22	23.81(14.02-33.09)d	0.40
	Deltamethrin	150	1.09±0.17	3.93(2.40-5.57)c	0.65
2 nd	Chlorpyrifos-methy	150	2.46±0.33	9.17(7.89-10.60)a	1.21
	Chlorpyrifos	150	2.55±0.35	24.93(21.43-30.57)c	0.04
	Etofenprox	150	2.48±0.23	17.78(15.60-20.26)b	2.08
	Etofenprox+PAP	150	2.86±0.34	424.11(374.08-485.87)d	9.32
	Deltamethrin	150	1.79±0.21	473.98(399.24-564.86)de	1.14
3 rd	Chlorpyrifos-methy	150	2.45±0.34	114.59(98.62-139.27)b	0.50
	Chlorpyrifos	150	2.80±0.34	135.58(119.27-155.13)bc	2.44
	Etofenprox	150	1.36±0.21	58.41(42.91-75.29)a	0.46
	Etofenprox+PAP	150	2.06±0.32	485.11(409.97-600.61)d	6.03
	Deltamethrin	150	2.01±0.32	542.78(444.70-643.79)dc	2.09
4 th	Chlorpyrifos-methy	150	3.27±0.36	123.19(108.51-137.98)a	0.23
	Chlorpyrifos	150	2.73±0.34	197.08(169.26-224.75)b	0.08
	Etofenprox	150	2.75±0.35	280.64(237.45-321.19)c	0.14
	Etofenprox+PAP	150	3.20±0.35	628.08(554.69-704.41)d	1.14
	Deltamethrin	150	2.96±0.35	992.75(861.43-1123.06)e	0.59
5 th	Chlorpyrifos-methy	150	3.18±0.26	238.45(213.95-266.12)a	0.53
	Chlorpyrifos	150	1.28±0.30	462.54(337.06-610.06)bc	0.66
	Etofenprox	150	2.26±0.32	344.75(289.97-401.90)b	0.04
	Etofenprox+PAP	150	2.24±0.32	744.41(634.28-874.34)d	4.02
	Deltamethrin	150	3.45±0.36	1266.67(1134.64-1413.38)e	7.89
6 th	Chlorpyrifos-methy	150	2.39±0.23	376.92(327.66-430.66)a	4.30
	Chlorpyrifos	150	1.33±0.31	584.40(344.68-767.45)bc	0.49
	Etofenprox	150	1.63±0.20	510.48(419.68-614.46)ab	0.46
	Etofenprox+PAP	150	1.81±0.32	1055.22(869.91-1387.55)d	0.07
	Deltamethrin	150	5.84±0.59	1801.33(1660.61-1947.68)e	0.56

[a] Concentration expressed in ppm as AI. Respective mean lethal concentrations followed by the same letter are not significantly different based on failure of 95% FL to overlap.

tested insecticides decreased significantly as larvae aged. LC$_{50}$ values for chlorpyrifos-methyl and chlorpyrifos increased significantly from 3rd instar larvae. For etofenprox+PAP and deltamethrin, LC$_{50}$ values increased significantly from 2nd instar larvae while etofenprox from 4th instar larvae.

The response of insects to insecticide exposure may be strongly affected by such factors as age, stage of development, sex, and nutritional status (El-aziz *et al.* 1969, Critchley 1972, Bratisten and Metcalf 1973, Dauterman and Hodgson 1978, Matsumura 1980, Aguayo and Villaneueva 1985). In many cases, it is also known that the success or failure of an insect to survive depends on its capacity to metabolize the toxicant and remove it from its body (Arias and Terriere 1962, Benke and Wilkinson 1971, Slama *et al.* 1974, Koehler *et al* 1993). Kuhr (1970) reported that several factors may play important roles in the differences between the toxicity of varied insecticides to the same insect and the toxicity of the same insecticides to several stages of insect; rate of penetration of insecticides through insect cuticle, rate of metabolism of insecticides, rate of conjugation of primary metabolites, and rate of excretion of insecticides and/or metabolites.

Our result shows that the developmental stage of the tobacco cutworm is a significant factor in deciding insecticide efficacy. For all the insecticides tested, the last instar larvae had higher LC_{50} values than newly hatched instar larvae. Differences in mortality depending on different instar larvae are probably due to enhanced insecticide metabolism as well as weight differences, although this difference remains to be clarified.

Based upon our data, control measures should be aimed at the first and/or second instar larvae. However, field applications of insecticides for controlling the tobacco cutworm often result in control failures because various stages of *S. litura* exist in natural populations. To manage field population of *S. litura*, therefore, it is important to select appropriate insecticides and decide a proper time of treatment.

Fig. 1 shows the relationships between various developmental stages of *S. litura* and their LC_{50} values. Various larval stages of *S. litura* and insecticide toxicity were positively correlated. Etofenprox+PAP was lowest toxic while chlorpyrifos-methyl was highest toxic to the newly hatched larvae. For the sixth instar larva, deltamethrin showed the lowest toxicity, with the steepest slope of regression equation ($R^2 = 0.9725$). Thus continuous application of deltamethrin in the field may cause repid development of insecticide resistance that results in the increase of populations surviving even after treatment. On the other hand, field application of chlorpyrifos-methyl will reduce effectively population of *S. litura* due to higher toxicity against all larval stages.

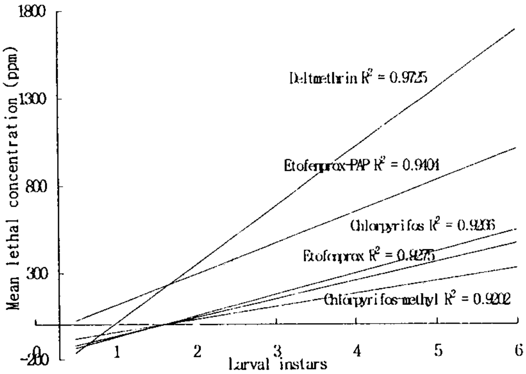

Fig. 1. Relationships between various larval stages of *S. litura* and their LC_{50} values.

Pot study

The effects of the insecticides for *S. litura* larvae on Chinese cabbage grown in pot are shown in Table 2. No significant differences in control efficacy were observed among each treated plots. Over 90% control efficacy at 5 d after treatment was achieved in all of the treated plots, except treatment with deltamethrin. Chlorpyrifos-methyl and chlorpyrifos showed excellent control effect. Because none of the insecticide is registered for controlling *S. litura* until now, four insecticides excluding deltamethrin may be effective for controlling *S. litura*. In addition, it is quite natural that rotation use should be needed to avoid or delay quick development of resistance to insecticides.

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Table 2. Control value of five insecticides to *Spodoptera litura* larvae in the Chinese cabbage pot

Insecticide			Application rate (g/l)	Mean survival rate[a] (%)		Control value[b] (%)
				3DAT	5DAT	
Chlorpyrifos-methyl	25%	EC	1	0	0	100a
Chlorpyrifos	25%	WP	1	0	0	100a
Etofenprox	20%	EC	1	5.0	3.3	95.8ab
Etofenprox+PAP	37%	WP	1	10.0	5.0	93.3ab
Deltamethrin	1%	EC	0.65	38.3	35.0	36.6b
Control			-	83.3	83.3	-

[a,b] For explanation, see text

* In a column, means followed by the same letter are not significantly different at the 5% level of Duncan's multiple range test (SAS Institute 1986).

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