ISJ 2: 75-81, 2005 ISSN 1824-307X

Short Communication

Sensitivity of the silkworm, *Bombyx mori* L. (Lepidoptera: Bombycidae) larvae to UV-irradiation

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Accepted May 31, 2005

Abstract

The effects of UV-radiation on some commercially relevant traits of three instars viz. 1st, 2nd and 3rd of the two multivoltine strains, Nistari-M and Urboshi-1 of the silkworm, *Bombyx mori* L. have been investigated. UV-rays reduced the weight of larvae, pupae and adults of both the strains and sexes of *B. mori* independently of the instar that has been treated. The cocoon weight, shell weight and shell ratios were also reduced due to UV-irradiation. Increased larval mortality was recorded at all the doses of UV-rays.

Key words: UV-radiation; *Bombyx mori* L. growth; cocoon characters; larval mortality

Introduction

In sericulture, the growth of various developmental stages of the mulberry silkworm, *Bombyx mori* L. is of paramount importance because the quality of successful cocoon crop depends mostly on a healthy larval growth.

Radiation studies have been extensively carried out in different insects (Calderon *et al.*, 1985; Mehta *et al.*, 1990, 1991; Islam *et al.*, 1992; Faruki and Khan, 1993; Sharma and Dwivedi, 1997; Hasan *et al.,* 1998). In silkworms, few attempts have been made to find out the radiation sensitivity on different developmental stages through the use of chemical agents and ionizing radiations (Mallik *et al.*, 1968; Park and Hyun, 1968; Subramany and Reddy, 1982; Tazima, 1983, 1984; Ali and Ali, 1998). It has been observed that radio-sensitivity varies according to species, strain, individual and even at different developmental stages of the individual (Tazima, 1978). Dose dependent sensitivity of silkworm growth to different forms of ionizing radiations have also been reported by Molnar *et al.* (1964), Murakami and Kondo (1964), Shankarnarayanan (1982) and Singh *et al.* (1990). Moreover, gamma radiation has been used to identify the resistant and less resistant strains of silkworm (Hirobe, 1974).

The Ultraviolet (UV) portion of the spectrum is widely used as germicide (Bruce, 1975), in embryological-physiological studies (Bodenstein, 1953) and for the surface disinfection of insect eggs from pathogens (Guerra, *et al.* 1968). In Bangladesh, some works have been conducted on the effect of gamma-rays on the eri-silkworm, *Samia cynthia ricini* (Rahman *et al.,* 1982; Khan and Khan, 1991) and *B. mori* (Rahman *et al.*, 1983a, b). Unfortunately, no investigation was done on the effect of ultraviolet radiation on the mulberry silkworm, *B. mori*. Keeping in view the importance and feasibility of the use of UV-rays the present investigation was undertaken to evaluate the effect of UV-irradiation on commercially relevant aspects of *B. mori*.

Materials and Methods

The multivoltine strains of the silkworm, *B. mori* used in the present investigation were Nistari-M and Urboshi-1. Newly-hatched larvae were brushed to wooden rearing trays (40 x 29 x 7.5 cm) and were reared on finely-chopped fresh, tender mulberry (*Morus*

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alba L.) leaves to get the 2nd and 3rd instar larvae . First instar larvae were exposed to UV-rays just after hatching from eggs, and the 2nd and 3rd instar larvae were irradiated just after completion of their moulting, i.e. no feeding was provided before irradiation. The larvae of all instars were irradiated with 254 nm wavelength of UV-rays at different durations (doses), e.g. 2, 4 and 8 min. A 15W germicidal lamp, GE15T8 measuring 20 x 4 cm was the source of UV radiation, emitting at a wavelength of 254 nm. For irradiation the test insects were kept in 15 cm diameter Petri dishes placed on the surface apart 12 cm from the lamp. Irradiated larvae were then reared on mulberry leaves in rearing trays up to pupation. A single batch of non-irradiated worms was simultaneously reared as controls on fresh mulberry leaves up to spinning. From the fourth instar onwards entire mulberry leaves were supplied to both irradiated and control groups. Food was provided four times a day. Three replications, each with 50 larvae, were made for each UV treatment and for controls. The rearing trays were kept in fine-netted cabinets.

The weight of larvae was determined at maturity, i. e. one day before spinning. Thirty larvae were taken randomly from each treatment and were individually weighed on an electric balance. Mature larvae were transferred to bamboo-made mountages for spinning cocoons. After spinning and pupation the cocoons were harvested and stored according to their sexes. The sex was determined by cutting cocoons with a sharp blade and observing the external genitalia.

Cocoons were then retained for adult emergence. Pupal and adult weight were individually recorded. The adult weight was determined after emergence but before coupling. The cocoon characters, i. e. whole cocoon and shell weight, and shell-ratio (%) were also noted. For each character and each treatment 30 males and 30 females were randomly selected. Data of all the characters were subjected to analyses of variance. Here, the variance ratio F was calculated from the ratio between treatment mean square and residual mean square and the value was compared with the tabulated value for significance. The differences between means were determined by the “Student-Newman-Keuls (SNK) test”. The mortality of *B. mori* larvae was observed up to pupation and data were corrected by Abbott’s (1925) formula.

All the experiments were conducted at a mean room temperature of 24 ± 2 °C.

Results and Discussion

The results on the effect of UV-rays on the weight of mature larvae, pupae and adults are shown in Tables 1, 2 and 3. It was found that the weight of larvae decreased with increased radiation doses at all the instars of both the strains of *B. mori* (P < 0.001 for Nistari and P < 0.05 for Urboshi) (Table 1). It was also observed that the effect of UV-rays was more pronounced at an early stage than an advanced stage.

Table 1 Effect of UV-radiation on the weight (mg) of mature *B. mori* larvae (N = 30)

Strains	Doses (min.)	Instars 1st Mean ± SE	Instars 2nd Mean ± SE	Instars 3rd Mean ± SE	F-ratio
Nistari-M	0 (Control)	1926.93 ± 15.03^{a}	1926.93 ± 15.03^{a}	1926.93 ± 15.03^{a}	
	2	1530.86 ± 19.68^{b}	1599.33 ± 21.74^{b}	1670.00 ± 17.75^{b}	(a) 23.91^{***}
	4	1472.10 ± 15.63^{b}	1703.16 ± 20.26^{b}	1656.26 ± 24.75^{b}	(b) 5.55^{*}
	8	1447.53 ± 20.97^{b}	1584.43 ± 20.68^{b}	1653.86 ± 20.57^{b}	
Urboshi-1	0 (Control)	1929.36 ± 20.92^{a}	1929.36 ± 20.92^{a}	1929.36 ± 20.92^{a}	
	2	1735.73 ± 27.16^{b}	1824.53 ± 50.29^{b}	1917.30 ± 18.20^{a}	(a) 6.92^{*}
	4	1735.20 ± 45.49^{b}	1726.30 ± 38.23^{bc}	1916.70 ± 26.32^{a}	(b) 6.25^{*}
	8	1710.80 ± 37.26^{b}	1693.96 ± 31.01^{c}	1822.76 ± 18.67^{a}	

(a) = between doses, (b) = between instars; * P < 0.05, *** P < 0.001
F = variance ratio. Means followed by the same letter in each instar of each strain are not significantly different at P = 0.05 (SNK test).

Table 2. Effect of UV-radiation on the weight (mg) of *B. mori* pupae (N = 30)

Strains	Doses (min.)	Instars			F-ratio
		1st Mean ± SE	2nd Mean ± SE	3rd Mean ± SE	
Nistari-M	0 (Control)	808.26 ± 10.59^{a} (914.60 ± 7.57^{k})	808.26 ± 10.59^{a} (914.60 ± 7.57^{k})	808.26 ± 10.59^{a} (914.60 ± 7.57^{k})	(a) 36.46^{***} (2.92^{NS}) (b) 4.19^{NS} (2.78^{NS})
	2	763.06 ± 9.28^{b} (891.80 ± 6.40^{k})	745.66 ± 10.28^{b} (895.86 ± 5.44^{k})	767.30 ± 8.56^{b} (892.10 ± 6.33^{k})	
	4	690.73 ± 7.92^{c} (799.26 ± 2.81^{l})	680.40 ± 6.48^{c} (893.63 ± 4.46^{k})	732.50 ± 7.44^{bc} (853.26 ± 7.39^{k})	
	8	645.50 ± 11.33^{d} (744.66 ± 8.17^{l})	607.23 ± 4.07^{d} (901.10 ± 5.03^{k})	694.86 ± 6.87^{c} (851.63 ± 8.65^{k})	
Urboshi-1	0 (Control)	810.13 ± 10.04^{a} (875.26 ± 9.60^{k})	810.13 ± 10.04^{a} (875.26 ± 9.60^{k})	810.13 ± 10.04^{a} (875.26 ± 9.60^{k})	(a) 6.07^{*} (5.07^{*}) (b) 1.44^{NS} (2.24^{NS})
	2	748.10 ± 11.30^{b} (857.20 ± 12.12^{k})	794.90 ± 8.77^{a} (870.26 ± 10.78^{k})	800.86 ± 8.12^{a} (858.60 ± 11.46^{k})	
	4	743.63 ± 10.35^{ab} (849.06 ± 17.60^{k})	694.20 ± 5.61^{b} (865.96 ± 8.05^{k})	794.33 ± 8.39^{a} (863.50 ± 13.42^{k})	
	8	731.73 ± 8.17^{ab} (783.80 ± 14.52^{l})	692.70 ± 4.36^{b} (843.66 ± 8.25^{k})	722.90 ± 4.92^{b} (847.86 ± 9.47^{k})	

(a) = between doses, (b) = between instars; * P < 0.05, *** P < 0.001
NS = Not significant. Data in parentheses indicate corresponding values in females.
F = variance ratio. Means followed by the same letter in each instar of each strain are not significantly different at P = 0.05 (SNK test).

There was a significant weight difference between the instars of both the strains (P < 0.05). In all the instars of Nistari, UV-rays deleteriously reduced the weight of male pupae (P < 0.001) in comparison to controls but produced no effect on the weight of female pupae (Table 2). The weight of male and female pupae of Urboshi was significantly reduced (P < 0.05). Similarly, the adult weight of both the strains and sexes were significantly reduced due to UV-irradiation (P < 0.01 for male and female of Nistari, and P < 0.001 and P < 0.01 respectively for male and female of Urboshi)(Table 3). There was no significant difference regarding weight between the instars of both the sexes of pupae and adults of the two strains. Lassota (1966), Shigematsu and Takeshita (1968) working with gamma-ray and Coulon (1969) working with X-ray on *B. mori* reported that higher doses either on the eggs or the larvae decreased the body weight that corroborates with the present findings. Similarly, Khan and Khan (1991) stated that the growth of the eri-silkworm, *S. cynthia ricini* was adversely affected when the eggs were irradiated with gamma rays. In the present investigation, significantly increased larval mortality was also recorded at all the instars and strains of *B. mori* due to UV-irradiation (Table 4).

The cocoon weight of the two strains of *B. mori* was adversely affected when larvae of different instars were irradiated with UV-rays. The lighter cocoons were recorded at all the doses of UV-rays in both the strains and instars in comparison to controls (Table 5). In Nistari male cocoon weight was significantly (P < 0.001) reduced whereas both male and female cocoons of Urboshi were severely affected (P < 0.05 and P < 0.01 respectively for male and female). The UV-rays produced no adverse effects on the shell weight of *B. mori* but except the male shells in 3rd instar of the strain Nistari-M, the weight was reduced at all the doses of UV-rays in comparison to controls, which was not statistically significant (Table 6). Similarly, the shell ratios (%) was not affected except in the males of Nistari where the shell ratios were significantly reduced (P < 0.001) due to UV-radiation (Table 6). Singh *et al.* (1990) also observed reduced cocoon and shell weight in *B. mori* due to gamma irradiation. Similar result was observed by Khan and Khan (1991) using gamma irradiation against the eggs of *S. cynthia ricini*.

Table 3. Effect of UV-radiation on the weight (mg) of *B. mori* adults (N = 30)

Strains	Doses (min.)	Instars			F-ratio
		1st	2nd	3rd	
		Mean ± SE	Mean ± SE	Mean ± SE	
Nistari-M	0 (Control)	342.73 ± 4.20^{a} (541.80 ± 5.77^{k})	342.73 ± 4.20^{a} (541.80 ± 5.77^{k})	342.73 ± 4.20^{a} (541.80 ± 5.77^{k})	$^{(a)}$ 14.24** (9.99**) $^{(b)}$ 0.97^{NS} (6.22*)
	2	326.80 ± 3.88^{a} (522.30 ± 4.75^{k})	317.36 ± 4.82^{ab} (557.66 ± 4.38^{k})	314.33 ± 3.20^{b} (566.73 ± 3.01^{k})	
	4	290.83 ± 4.30^{b} (495.53 ± 4.21^{l})	303.70 ± 2.54^{b} (514.96 ± 3.13^{l})	308.93 ± 2.66^{b} (551.66 ± 4.67^{k})	
	8	263.93 ± 3.56^{c} (480.60 ± 4.13^{l})	265.30 ± 4.91^{c} (490.86 ± 4.77^{l})	303.63 ± 2.52^{b} (512.93 ± 3.77^{l})	
Urboshi-1	0 (Control)	343.50 ± 3.83^{a} (700.06 ± 6.63^{k})	343.50 ± 3.83^{a} (700.06 ± 6.63^{k})	343.50 ± 3.83^{a} (700.06 ± 6.63^{k})	$^{(a)}$ 26.18*** (18.56**) $^{(b)}$ 0.69^{NS} (2.59^{NS})
	2	329.93 ± 4.72^{b} (639.80 ± 3.93^{l})	331.36 ± 3.78^{b} (634.16 ± 4.67^{l})	338.00 ± 3.08^{ab} (640.16 ± 9.13^{l})	
	4	321.93 ± 3.09^{bc} (546.76 ± 6.00^{m})	320.83 ± 3.03^{c} (614.70 ± 4.50^{l})	330.96 ± 2.98^{b} (602.40 ± 3.17^{lm})	
	8	318.53 ± 3.32^{c} (489.10 ± 4.93^{m})	314.10 ± 2.99^{c} (580.10 ± 5.95^{l})	310.83 ± 4.08^{c} (574.03 ± 5.78^{m})	

(a) = between doses, (b) = between instars; * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$
NS = Not significant. Data in parentheses indicate corresponding values in females.
F = variance ratio. Means followed by the same letter in each instar of each strain are not significantly different at P = 0.05 (SNK test).

Table 4. Effect of UV-radiation on the mortality of *B. mori* larvae

Strains	Doses (min.)	Corrected (%) mortality / Instars			F-ratio
		1st	2nd	3rd	
Nistari-M	2	2.04	2.04	0.67	$^{(a)}$ 78.50***
	4	5.44	4.08	4.75	$^{(b)}$ 0.85^{NS}
	8	6.12	6.80	6.12	
Urboshi-1	2	2.71	8.16	2.71	$^{(a)}$ 11.84**
	4	3.39	3.39	4.75	$^{(b)}$ 2.30^{NS}
	8	6.80	12.24	8.16	

Control mortality of both the strains and all the instars = 2.00%, (a) = between doses, (b) =between instars, ** $P < 0.01$, *** $P < 0.001$; NS = Not significant. F = variance ratio.

Table 5. Effect of UV-radiation on the cocoon weight (mg) of *B. mori* (N = 30)

Strains	Doses (min.)	Instars 1st Mean ± SE	2nd Mean ± SE	3rd Mean ± SE	F-ratio
Nistari-M	0 (Control)	886.62 ± 10.73^{a} (1004.93 ± 7.52^{k})	886.62 ± 10.73^{a} (1004.93 ± 7.52^{k})	886.62 ± 10.73^{a} (1004.93 ± 7.52^{k})	$^{(a)}$ 60.19*** (3.25^{NS}) $^{(b)}$ 5.52* (2.65^{NS})
	2	842.06 ± 9.59^{b} (982.86 ± 6.54^{k})	823.26 ± 10.34^{b} (982.36 ± 5.72^{k})	851.96 ± 8.48^{b} (980.26 ± 6.52^{k})	
	4	766.49 ± 8.13^{c} (879.86 ± 2.96^{m})	751.70 ± 7.46^{c} (983.20 ± 4.40^{k})	815.53 ± 7.62^{c} (941.20 ± 7.28^{k})	
	8	718.56 ± 11.62^{d} (820.30 ± 8.38^{m})	679.63 ± 4.12^{d} (978.00 ± 4.96^{k})	744.02 ± 6.74^{d} (937.80 ± 8.67^{k})	
Urboshi-1	0 (Control)	955.40 ± 11.32^{a} (1039.40 ± 10.41^{k})	955.40 ± 11.32^{a} (1039.40 ± 10.41^{k})	955.40 ± 11.32^{a} (1039.40 ± 10.41^{k})	$^{(a)}$ 9.25* (14.12**) $^{(b)}$ 0.20^{NS} (1.49^{NS})
	2	871.36 ± 11.41^{a} (1001.36 ± 12.62^{l})	930.63 ± 7.91^{a} (1018.06 ± 12.81^{k})	931.86 ± 12.80^{a} (1019.60 ± 9.01^{k})	
	4	881.56 ± 12.06^{a} (1015.83 ± 17.02^{kl})	820.00 ± 5.55^{b} (1007.42 ± 8.25^{kl})	807.26 ± 12.96^{b} (1011.46 ± 13.50^{k})	
	8	867.03 ± 8.67^{a} (938.36 ± 14.45^{m})	812.50 ± 4.28^{b} (983.66 ± 6.04^{l})	836.40 ± 5.38^{b} (984.36 ± 8.35^{l})	

(a) = between doses, (b) = between instars, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$,
NS = Not significant. Data in parentheses indicate corresponding values in females.
F = variance ratio. Means followed by the same letter in each instar of each strain are not significantly different at $P = 0.05$ (SNK test).

Table 6. Effect of UV-radiation on the shells of *B. mori* (N = 30)

Strains	Doses (min.)	Shell weight / Instars 1st Mean ± SE	Shell weight / Instars 2nd Mean ± SE	Shell weight / Instars 3rd Mean ± SE	F-ratio	Shell ratios (%) / Instars 1st Mean ± SE	Shell ratios (%) / Instars 2nd Mean ± SE	Shell ratios (%) / Instars 3rd Mean ± SE	F-ratio
Nistari-M	0 (Control)	78.36 ± 1.37 (90.33 ± 1.01)	78.36 ± 1.37 (90.33 ± 1.01)	78.36 ± 1.37 (90.33 ± 1.01)		8.84 ± 0.18 (8.99 ± 0.12)	8.84 ± 0.18 (8.99 ± 0.12)	8.84 ± 0.18 (8.99 ± 0.12)	
	2	79.00 ± 1.22 (91.06 ± 1.13)	77.60 ± 0.61 (86.56 ± 1.08)	84.66 ± 1.44 (88.16 ± 1.41)	(a) 2.64^{NS} (4.22^{NS})	9.38 ± 0.16 (9.26 ± 0.12)	9.43 ± 0.14 (8.81 ± 0.10)	9.94 ± 0.19 (8.99 ± 0.19)	(a) 26.80*** (0.73^{NS})
	4	75.76 ± 0.81 (80.60 ± 0.78)	71.30 ± 0.65 (89.56 ± 0.42)	83.10 ± 1.11 (87.83 ± 1.07)	(b) 6.98* (0.90^{NS})	9.88 ± 0.12 (9.16 ± 0.08)	9.49 ± 0.11 (9.11 ± 0.06)	10.19 ± 0.14 (9.33 ± 0.13)	(b) 2.57^{NS} (2.03^{NS})
	8	73.06 ± 1.42 (75.63 ± 1.46)	72.40 ± 0.53 (76.90 ± 0.61)	79.16 ± 1.18 (86.26 ± 1.29)		10.18 ± 0.22 (9.22 ± 0.18)	10.65 ± 0.09 (7.86 ± 0.08)	10.64 ± 0.16 (9.20 ± 0.15)	
Urboshi-1	0 (Control)	144.90 ± 2.67 (164.13 ± 3.12)	144.90 ± 2.67 (164.13 ± 3.12)	144.90 ± 2.67 (164.13 ± 3.12)		15.16 ± 0.23 (15.79 ± 0.30)	15.17 ± 0.23 (15.79 ± 0.30)	15.17 ± 0.23 (15.79 ± 0.30)	
	2	123.26 ± 2.61 (144.16 ± 2.50)	135.73 ± 0.69 (147.80 ± 1.52)	131.00 ± 3.81 (161.00 ± 2.60)	(a) 4.47^{NS} (2.47^{NS})	14.15 ± 0.33 (14.40 ± 0.26)	14.58 ± 0.13 (14.52 ± 0.22)	14.06 ± 0.32 (15.79 ± 0.22)	(a) 3.19^{NS} (0.61^{NS})
	4	137.93 ± 3.37 (166.76 ± 2.58)	125.66 ± 1.46 (141.46 ± 1.03)	122.93 ± 3.10 (147.96 ± 2.77)	(b) 0.90^{NS} (0.95^{NS})	15.65 ± 0.33 (16.42 ± 0.37)	15.32 ± 0.20 (14.04 ± 0.15)	15.23 ± 0.27 (14.63 ± 0.28)	(b) 1.70^{NS} (1.41^{NS})
	8	135.30 ± 2.79 (154.60 ± 3.02)	119.86 ± 0.62 (140.00 ± 1.94)	113.50 ± 2.41 (136.50 ± 2.97)		15.60 ± 0.30 (16.48 ± 0.37)	14.75 ± 0.11 (14.23 ± 0.19)	13.57 ± 0.26 (13.87 ± 0.27)	

(a) = between doses, (b) = between instars, * P < 0.05, *** P < 0.001, NS = Not significant.
Data in parentheses indicate corresponding values in females. F = variance ratio.

Hirobe (1974) stated that in silkworms, growth and other quantitative characters are changed by gamma-irradiation depending upon dose rate, total dosage, developmental stage, temperature, moisture and other environmental conditions. It has been demonstrated that the developmental stages of insects renew their cells and tissues, and a particular stage of these animals determine their radio-sensitivity to ionizing radiation (Allotey, 1985). In the present investigation dose dependent sensitivity was observed in the strains of Nistari-M and Urboshi-1 and in different instars of *B. mori*. Moreover, UV-radiation reduced the relevance of some commercial traits e.g. larval, pupal, adult, cocoon and shell weight, and increased larval mortality in *B. mori*, which are very much undesirable from the economic point of view. Future experiments with an array of doses on various developmental stages of *B. mori* and ecological factors are greatly to be desired.

Acknowledgements
The authors remain grateful to the Chairman, Department of Zoology, Rajshahi University, for providing necessary laboratory facilities.

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