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IMPACT OF NICKEL MEDIATED ARTIFICIAL DIET ON BIOLOGY OF *SPODOPTERA LITURA* F. (LEPIDOPTERA: NOCTUIDAE)

SHARMILA CHOHAN*[1], S. C. VERMA[2], R. S. CHANDEL[3], NEERJA RANA[4] AND MEENA THAKUR[5]
[1]Deptartment of Environmental Science,
Dr. Y S Parmar University of Horticulture and forestry, Nauni, Solan -173 230 (H P), INDIA
[2]Deapartment of Seed Science and Technology,
Dr. Y S Parmar University of Horticulture and forestry, Nauni, Solan - 173 230 (H P), INDIA
[3]Regional Horticulture and Training Station, Sharbo, Kinnaur,
Dr. Y S Parmar University of Horticulture and forestry, Nauni, Solan - 173 230 (H P), INDIA
[4]Department of Basic Science,
Dr. Y S Parmar University of Horticulture and forestry, Nauni, Solan - 173 230 (H P), INDIA
[5]Department of Environmental Science,
Dr. Y S Parmar University of Horticulture and forestry, Nauni, Solan - 173 230 (H P), INDIA
e-mail: sharmila.chauhan15@gmail.com

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***Corresponding author**

ABSTRACT
The pure culture of tobacco caterpillar (*Spodoptera litura* F.) was maintained under laboratory conditions. Artificial diet impregnated with various concentrations of nickel (T_1-0, T_2-1, T_3-5, T_4-10, T_5-15, T_6-20, T_7-30, T_8-40 mg Ni/kg) were offered continuously to the larvae for three generations. Each treatment was replicated thrice. Treatment T_8 (40 mg Ni/kg) recorded lowest fecundity (472.56 eggs/female) and fertility (73.12%). Significantly lowest fecundity (394.58 eggs/female) and fertility (73.32%) was recorded in generation-3. Minimum incubation period (3.0 days) was recorded with treatment T_2 (5 mg Ni/kg) whereas, maximum (4.0 days) was recorded in treatment T_7 (40 mg Ni/kg). Minimum incubation period (2.96 days) was recorded in generation -1. Maximum larval period was recorded in Treatment T_7 (40 mg Ni/kg) whereas, pupal period was maximum at 1 mg Ni/kg. Longest life cycle was recorded at Treatment T_7 (40 mg Ni/kg) 33.64 days. Statistically minimum developmental period 29.76 days was observed in generation-1 as compared to generation -2 and generation-3. *Spodoptera litura* F. showed dose dependent relationship with the nickel doses in the artificial diet.

INTRODUCTION

There is growing concern on presence of heavy metals in the environment. Due to rapid industrialization heavy metals are excessively released into the environment and this has created a major global concern (Abhijit *et al.*, 2010).Insects living in polluted areas accumulate heavy metals, particularily Ni and Cu (Heliovaara *et al.*, 1987; Zvereva *et al.*, 2003). Metals entering the soil constitute more lasting form of pollutants due to their accumulation in soil. Waste water from industries, when used for irrigation of vegetable crops contaminates growing crops. Though heavy metals are not essential for the plant growth yet they are taken up by the roots and translocated into the leaves in many plant species (Marschner, 1983). Vegetable crops are attacked by sundry of insect pests which are directly or indirectly influenced by heavy metals particularly Ni (Heliovaara *et al.*, 1987). Himachal Pradesh is well known for off- season commercial vegetable crop production viz., tomato, cauliflower, cabbage, pea, potato etc. Vegetable uptake of metals from soil is one of the major pathways by which metals enter into food chain and accumulate to high concentrations. When plants' based food stuffs are consumed, may cause serious risk to human health (Zurera *et al*, 1984; Islam *et al.*, 2007).Because insect behaviours are key contributors to the ecology of insect interactions with other plant and animal species, as well as with their abiotic environments, these behaviours are critical to the stability and diversity of ecosystems (Fishers,1998). Despite the importance of insects in most ecosystems and the worldwide pollution of systems by heavy metals, little information is available on the effects of metal and metalloid pollution on the behaviour of insects. *Spodoptera litura* F. is a lepidopteran pest that feeds on nearly 112 cultivated crops all over the world and about 60 plant species from India (Garad *et al.*, 1985) . Sharma and Bisht (2008) reported tobacco, cotton, ground nut , jute, lucerne, maize, rice, soybean, tea, cauliflower, cabbage, capsicum, potato and castor to be the major host plants for *S litura*. The impact of heavy metal contaminated artificial diet on biology of *S. litura* has not been studied so far under present environmental conditions. Therefore, the present investigation was carried out to know the impact of heavy metal contaminated artificial diet on biology of *S. litura*.

MATERIALS AND METHODS

The pure culture of Tobacco caterpillar (*Spodoptera litura* F.) was maintained under laboratory conditions. Cotton swab soaked in 25 per cent sugar solution served as food to the adults. Freshly hatched larvae were reared on chick-pea artificial diet which was prepared as per method of Anonymous (1988). There were eight treatments (T_1-0, T_{2-} 1, T_{3-} 5, T_4-10, T_{5-} 15, T6- 20, T_7-30, T_{8-} 40 mg/kg) including control. Each treatment was replicated thrice. In each replication ten larvae of *S. litura* were released and each larva was kept in individual vials containing weighed quantity of artificial diet.

Total development period

For calculating total development period the duration between egg laying to hatching, larval to pupal period and pupal to adult emergence was calculated

RESULTS AND DISCUSSION

Fecundity

Artificial diet impregnated with 1 mg Ni/kg (T_1) recorded maximum fecundity (767.22) which differed statistically with rest of the treatments. Lowest fecundity 472.56 was recorded at treatment T_8 40 mg Ni/kg. The maximum number of eggs (956.17 eggs/female) recorded in generation-1 differed significantly with generation-2 (556.25 eggs/female) as well as generation -3 (394.58 eggs/female) which could be due to heavy metal accumulation in larval period and decrease in adult longevity. There is strong correlation between pupal mass and fecundity in the *S. litura*. Similar to present findings Gorur (2007) also reported that heavy metals affected reproduction in successive generations of insects. Daniel (1994) and Forrest (1996) reported that adult survival and fecundity were reduced in blow-fly by constant exposure of cadmium. Moe *et al*. (2001) reported that reduction of fecundity in the adult stage seems to be caused directly by the cadmium accumulated during the larval stage.

Fertility

Maximum fertility (85.57%) was recorded at T_1 (1 mg Ni/kg) which was statistically at par with 5 mg Ni/kg (83.25%) and 10mg Ni/kg (81.65%). The minimum fertility (73.12%) was recorded with artificial diet impregnated with 40 mg Ni/kg which was statistically at par with 30 mg Ni/kg (75.16%). Maximum fertility (88.74%) was recorded in generation -1 followed by generation -2 (78.21%) and generation-3 (73.32%), all differed significantly with each other. Artificial diet impregnated with 1mg Ni/kg nickel recorded 85.62 per cent fertility in generation-2 which was statistically at par with 5 mg Ni/kg (84.90%), 10mg Ni/kg (82.81%) and control (85.31%) in the same generation and control (83.63%) in the generation -3 as well as 1 mg Ni/kg (87.61%), 5 mg Ni/kg (87.97%), 10 mg Ni/kg (89.87%), 15 mg Ni/kg (87.36%) and 20 mg Ni/kg (89.14%) in generation -1.The minimum fertility (63.01%) recorded with artificial diet impregnated with 40 mg Ni/kg (T_8) in generation -3 was statistically at par with 30 mg Ni/kg (65.18%) (T_7) in the same generation and with same dose in generation-2 (65.51%). Maximum fertility (88.74%) recorded in generation-1 differed significantly with generation-2 (78.21%) as well as generation-3 (73.32%) which could be due to accumulation of nickel in eggs which affected poor accumulation of egg yolk and failure of eggs to hatch in *S. Litura*. Similarly Sheikh *et al*. (2010) observed that hatchability per cent of eggs laid with $CdCl_2$, $CuSO_4$, Pb (NO_3) and Hg (NO_3) was significantly decreased to 37, 73, 80 and 39 per cent, respectively as compared to 97 percent in control.

Incubation period

Minimum incubation period (3.0 days) was recorded with artificial diet impregnated with 5 mg Ni/kg which was statistically at par with 1 mg Ni/kg (3.11 days), 10 mg Ni/kg (3.29 days) as well as control (3.0 days). Artificial diet mediated with 15 mg Ni/kg resulted 3.50 days incubation period which was statistically at par with 20 mg Ni/kg (3.66 days). Maximum incubation period (4.00 days) was recorded with artificial diet impregnated with 40 mg Ni/kg (T_8) which was statistically at par with 30 mg Ni/kg (3.79 days). Minimum incubation period (2.96 days) was recorded in generation -1 which differed statistically with generation -2 (3.54 days) and generation -3 (3.76 days). The minimum incubation period (2.67 days) recorded with artificial diet impregnated with 5 mg Ni/kg (T_2) in generation -1 was statistically at par with all the treatments of same generation as well as 1 mg Ni/kg, 5 mg Ni/kg and control (each 3.0 days) of generation -2 and control (3.00

Table 1: Effect of nickel (Ni) on fecundity and fertility of *S. litura* F. in different generations

Treatment	No. of eggs/Female Generation				Fertility (%)			
	1	2	3	Mean	1	2	3	Mean
T_1 (Control)	953.00 (30.87)*	775.67 (27.85)	651.67 (25.53)	793.44 (28.08)	87.83 (69.58)**	85.31 (67.47)	83.63 (66.14)	85.59 (67.73)
T_2 (1mg/kg)	955.00 (30.90)	743.33 (27.26)	603.33 (24.56)	767.22 (27.58)	87.61 (69.41)	85.62 (67.73)	83.47 (66.05)	85.57 (67.73)
T_3 (5mg/kg)	950.33 (30.83)	686.67 (26.20)	555.00 (23.56)	730.67 (26.86)	87.97 (69.71)	84.90 (67.19)	76.87 (61.26)	83.25 (66.05)
T_4(10mg/kg)	969.33 (31.13)	556.00 (23.58)	436.67 (20.89)	654.00 (25.20)	87.87 (69.62)	82.81 (65.60)	74.26 (59.57)	81.65 (64.93)
T_5(15 mg/kg)	949.00 (30.81)	516.67 (22.73)	333.33 (18.25)	599.67 (23.93)	87.36 (69.17)	77.49 (61.74)	72.54 (58.42)	79.13 (63.11)
T_6(20mg/kg)	950.00 (30.82)	451.67 (21.25)	253.33 (15.91)	551.67 (22.66)	89.14 (70.77)	75.05 (60.10)	67.57 (55.53)	77.25 (62.13)
T_7(30mg/kg)	961.67 (31.01)	396.67 (19.91)	190.00 (13.78)	516.11 (21.57)	91.34 (72.88)	68.97 (56.16)	65.18 (53.95)	75.16 (61.00)
T_8(40 mg/kg)	961.00 (31.00)	323.33 (17.98)	133.33 (11.53)	472.56 (20.17)	90.85 (72.41)	65.51 (54.04)	63.01 (52.60)	73.12 (59.68)
Mean	956.17 (30.92)	556.25 (23.35)	394.58 (19.25)	635.67 (24.51)	88.74 (70.44)	78.21 (62.50)	73.32 (59.19)	80.09 (64.05)
$CD_{(0.05)}$					$CD_{(0.05)}$			
Treatment		: (0.35)			Treatment		: (2.43)	
Generation		: (0.21)			Generation		: (1.49)	
Generation x Treatment		: (0.60)			Generation x Treatment		: (4.21)	

*Figures in parenthesis are square root transformation; ** Figures in parenthesis are arc sine transformations

Table 2: Effect of nickel (Ni) mediated artificial diet on incubation, larval and pupalperiodof*S. litura*. F. in different generations

Treatment	Incubation Period (days) Generation				Larval Period (days)				Pupal Period (days)				Total developmental period (days)			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
T_1 (Control)	3.00	3.00	3.00	3.00	16.93	16.93	16.97	16.94	8.67	8.67	8.67	8.67	28.60	28.60	28.63	28.61
T_2 (1mg/kg)	3.00	3.00	3.33	3.11	16.97	17.03	17.11	17.04	8.67	8.67	8.33	8.56	28.63	28.67	28.80	28.70
T_3 (5mg/kg)	2.67	3.00	3.33	3.00	17.37	17.57	17.57	17.50	8.67	8.33	8.00	8.33	28.67	28.87	28.93	28.82
T_4 (10mg/kg)	3.00	3.33	3.53	3.29	17.87	18.47	19.20	18.51	8.33	8.00	7.67	8.00	29.17	29.67	30.50	29.78
T_5 (15mg/kg)	3.00	3.67	3.83	3.50	18.83	19.60	20.94	19.79	8.00	7.67	7.33	7.67	29.77	30.83	32.20	30.93
T_6 (20mg/kg)	3.00	3.97	4.00	3.66	19.73	20.53	21.62	20.63	7.67	7.33	7.00	7.33	30.23	31.70	32.77	31.57
T_7 (30mg/kg)	3.00	4.00	4.37	3.79	20.97	21.93	22.71	21.87	7.33	7.00	6.67	7.00	31.13	32.73	33.93	32.60
T_8 (40mg/kg)	3.00	4.33	4.67	4.00	22.07	23.23	23.86	23.05	7.00	6.67	6.33	6.67	31.87	33.97	35.10	33.64
Mean	2.96	3.54	3.76	3.42	18.84	19.30	19.99	19.38	8.04	7.79	7.50	7.78	29.76	30.63	31.36	30.58
$CD_{(0.05)}$					$CD_{(0.05)}$				$CD_{(0.05)}$				$CD_{(0.05)}$			
Treatment		: 0.33			Treatment		: 0.04		Treatment		: 0.47		Treatment		: 0.62	
Generation		: 0.20			Generation		: 0.02		Generation		: 0.29		Generation		: 0.38	
Generation x Treatment		: 0.57			Generation x Treatment		: 0.07		Generation x Treatment		: NS		Generation x Treatment		: 1.08	

days) of generation -3. Artificial diet mediated with 30 mg Ni / kg (T_7) in generation -2 and 20 mg Ni/kg in generation -3 recorded equal incubation period (4.00 days) which could be due to chronic exposure of larva to contaminated diet and accumulation of heavy metal in insect body. The present findings are in confirmation with the findings of Sildanchandra and Crane, (2000) who reported that high cadmium concentration increases the larval duration of holometabolous insects. According to Barbosa *et al*. (1983) chronic exposure of gypsy moth larvae to cadmium or unsuitable host plant led to a decrease in pupal duration.

Total larval period

It is evident from Table 1. that the larva fed on artificial diet mediated with 1 mg Ni/kg resulted minimum larval period (17.04 days) which differed statistically with 5 mg Ni/kg (17.50 days) as well as with rest of treatments. The larva fed on artificial diet mediated with 10 mg Ni/kg resulted 18.51 days larval period which differed statistically with 15 mg Ni/kg (19.79 days). A total larval period of 20.63 and 21.87 days was recorded when larva fed on artificial diet mediated with 20 mg Ni/kg and 30 mg Ni/kg, respectively. The longest larval period (23.05 days) was recorded with artificial diet mediated with 40 mg Ni/kg. Larva fed on untreated diet (control) took minimum time (16.94 days) to develop into pupa. Significantly minimum larval period (18.84 days) was recorded in generation-1 followed by generation-2 (19.30 days) and generation-3 (19.99 days). The larva fed on artificial diet mediated with 30 mg Ni/kg took 20.97 days to complete larval period in generation-1 which was statistically at par with 15 mg Ni/kg (20.94 days) in generation-3 which could be slow growth as a physiological response of insect to chemical stress The present findings are in confirmation with the findings of Sildanchandra and Crane, (2000) who reported that high cadmium concentration increases the larval duration of holometabolous insects.

Pupal period

Minimum pupal period (6.67 days) was recorded with artificial diet impregnated with 40 mg Ni/kg and maximum pupal period with 1 mg Ni/kg (8.56 days), the last was statistically at par 5 mg Ni/kg (8.33 days) as well as control (8.67 days). In all the treatments pupation time was shorter than control (8.67 days). Artificial diet mediated with 10, 15, 20 and 30 mg Ni/kg resulted 8.0, 7.67, 7.33 and 7.00 days pupal period, respectively , the earlier two were statistically at par with each other. Maximum pupal period (8.04 days) was recorded in generation -1 which was statistically at par with generation -2 (7.79 days) and differed statistically with generation -3 (7.50 days), the last two were statistically at par with each other. Which may be due to chronic exposure of larvae to heavy metal contaminated diet and accumulation of heavy metal in larva. The present findings are in confirmation with the findings of Barbosa *et al*. (1983) who reported that chronic exposure of gypsy moth larvae to cadmium or unsuitable host plant led to a decrease in pupal duration.

Total developmental period

It is clear from Table 2 that minimum total developmental period (28.70 days) of *S. litura* F. was recorded with artificial diet treated with 1mg Ni/kg which was statistically at par with 5 mg Ni/kg (28.82 days) as well as control (28.61). Maximum total developmental period (33.64 days) was recorded with artificial diet mediated with 40 mg Ni/kg which differed significantly with 30mg Ni/kg (32.60 days). Artificial diet impregnated with 10mg Ni/kg resulted 29.78 days total developmental period which differed statistically with 15 mg Ni/kg (30.93 days). Minimum total developmental period (29.76 days) was recorded in generation-1 which was statistically different from generation -2 (30.63 days) as well as generation-3 (31.36 days). Minimum total developmental period (28.63days) recorded with 1 mg Ni/kg in generation-1 was statistically at par with 5 mg Ni/kg (28.67 days), 10 mg Ni/ kg (29.17 days) and control (28.60 days) in the same generation and 1 mg Ni/kg (28.67 days) 5 mg Ni/kg (28.87 days), 10 mg Ni/kg (29.67 days) and control (28.60 days) in generation-2 as well as 1 mg Ni/kg (28.80days) , 5 mg Ni/kg (28.93days) and control (28.63 days) in generation -3 which could be due to chronic exposure of insect to contaminated diet and subsequent heavy metal accumulation in larva which reduce the growth of larva.These findings are in confirmation with the finding of Smit *et al*. (2004) who observed that Zn @ 5mg Zn/dry food led to increase of developmental period *of Folsomia Candida* Zheng-Tian *et al*. (2011) reported that cadmium in food significantly led to increase in developmental

period of *Pirata subpiraticus*. Significant prolongation of gypsy moth larval development was obtained after acute or chronic exposure to cadmium at a concentration of 100 μg/g (Ortel*et al.*, 1993; Gintenreiter*et al.*, 1993; Ilijin *et al.*, 2010).

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