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The Influence of Cadmium on the Food Consumption and Utilization of the Cotton Leaf Worm Spodoptera littoralis (Boisd.) (Lepidoptera: Noctuidae)

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Abstract. The third, fourth, fifth, and sixth instars of the cotton leaf worm *Spodoptera littoralis* (Boisduval, 1833) were reared on castor bean leaves *Ricinus communis (*Linnaeus, 1753*)* treated with cadmium 100 mg $CdCl_2$/kg, using the dipping method, to evaluate the effect of cadmium (Cd) on nutritional indices. It was observed that the consumption index was significantly decreased at all the studied instars except for the third instar. The absorptive capacity, in terms of approximate digestibility, was significantly decreased at the sixth instar. The food utilization efficiencies, in terms of the conversion of ingested and digested food (ECD) to biomass, were significantly decreased at both fourth and fifth instars. Moreover, the ECD was significantly decreased at the sixth instar. The growth rate decreased at the different studied instars except for the sixth instar.

Keywords: *Spodoptera littoralis,* Heavy metals, Cadmium treatment, Nutritional indices

Introduction

The cotton leaf worm, *Spodoptera littoralis* (Boisduval, 1833) (Lepidoptera: Noctuidae), is one of the most destructive agricultural lepidopteran pests in Egypt as well as Mediterranean and Middle East countries (ADHAM *et al.,* 2005a; TIESSEN, 2012).

Cadmium (Cd) is a non–essential toxic heavy metal and it is highly ranked on the EU list of hazardous substances (ALLWAY, 1995). It has received considerable attentions over the past years as a result of increased environmental burdens from industrial, agricultural, energy, and municipal sources (WAGNER, 1993). A significant amount of cadmium can be found near mines and zinc smelters, on fertilizer-treated lands, industrial sewage sludge, and disposal sites of batteries. Cadmium exerts a negative impact on living organisms and accumulates in food chains (ROBERTS *et al.*, 1979). At organism level, it affects food consumption and digestibility (MIGULA & BINKOWSKA, 1993; FOUNTAIN & HOPKIN, 2001; VAN OOIK *et al.*, 2007). Also, cadmium interferes with the important biological processes (BUCHWALTER *et al.,* 2008). It was also found that the ephemeropterid larvae, *Baetis thermicus (*Uéno, 1931), collected from a metal-contaminated river in Japan, accumulated cadmium heavily in the body as indicated by LINDQVIST & BLOCK (1994).

The relationships between food consumption and growth of different instars of *S. littoralis* caused by metal contamination were less studied. Hence, the aim of this research is to investigate the effect of Cd on food utilization efficiencies such as approximate digestibility (AD), the efficiency of conversion of ingested food (ECI), the efficiency of conversion of

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digested food (ECD), growth rate (GR) and consumption index (CI) of the third, fourth, fifth, and sixth instars of *S. littoralis*.

Material and Methods

Insect rearing. The colony of *S. littoralis* was started with egg patches obtained from a standard laboratory colony maintained in the Department of Entomology, Faculty of Science, Cairo University. Newly hatched larvae were placed in plastic boxes (12 × 6 × 18 cm). Larvae were fed on fresh castor bean leaves, *Ricinus communis* (Linnaeus, 1753), until pupation. The culture was kept at 25 ± 2°C, 65 ± 5%R. H. and 12:12 hours (D:L) photoperiod.

Cadmium treatment. The heavy metal Cd was obtained in the form of $CdCl_2$ (Sigma-Aldrich®). Newly hatched third, fourth, fifth and sixth instars of *S. littoralis* were freely fed on fresh *R. communis* leaves dipped in 100 mg $CdCl_2$/kg (BAGHBAN *et al.*, 2014) for 10 seconds, then air-dried at room temperature (KRISHNAPPA & ELUMALAI, 2012; MOADELI *et al.*, 2014). Each experiment was replicated three times of twenty larvae each. The remaining diet was replaced regularly with freshly treated one at every 24 hours. The experiment was started with larvae hatched in the same day and were offered daily Cd-contaminated food from hatching till pupation.

Effects of cadmium on nutritional indices. The fresh weight of larvae, faeces, and of leaf consumed, and weight gain of larvae were recorded regularly. All uneaten food and faeces excreted were collected and immediately frozen; these matters were later dried at 105ºC in an oven (Thermo Scientific® Compact Oven) and weighed using analytical balance (Mettler® M22) according to ADHAM *et al.* (2005a,b) for calculating the food utilization. Exuviae were measured with faeces since they were considered as parts of the insect at the end of the experiment as suggested by REESE & BECK (1976).

Nutritional indices of the 3rd, 4th, 5th and 6th instars were calculated using standard gravimetric procedures described by WALDBAUER (1968) as follows:

- Consumption index (CI) = F/TA,
- Approximate digestibility (AD) = 100 × (F-E)/F,
- Efficiency of conversion of ingested food into biomass (ECI) = (G/F) × 100,
- Efficiency of conversion of digested food into biomass (ECD) = (P/F- E) × 100,
- Growth rate (GR) = P/TA,

where:

A = fresh weight of larvae during the feeding period
E = dry weight of produced feces
F = dry weight of food eaten
G = weight gain at the end of the feeding period
P = dry weight of the biomass of larvae
T = duration of feeding (days)

Statistical analysis. All data were presented as mean ± SD. Data were analyzed using one-way analysis of variance (ANOVA) and Duncan's multiple range test. All statistical computations were carried out using SAS program (SAS INSTITUTE, 2002). Significance was set at $P < 0.05$.

Results and Discussion

The Cd-treatment decreased significantly the CI ($P < 0.05$) compared to the control at all the instars, except for at the 1st instar where the change was insignificant (Table 1). The CI was steadily decreased through the studied instars, with a significant difference only between the 3rd and the other instars (Table 1). This may be due to the findings declared by BAGHBAN *et al.* (2014). Our results were in agreement with those declared by HARE (1992); who found that "non-essential" elements such as Cd, even at low concentrations, are toxic for organisms.

Approximate digestibility significantly decreased ($P < 0.05$) due to Cd treatment only at the 6th instar compared to the control (Table 1). With advancing age, significant difference ($P < 0.05$) was attained only between the 6th instar and the remaining instars (Table 1). Such decrease in AD could be due to the metal toxicity which impaired food absorption as suggested by YAZDANI *et al.* (2014).

Table 1. The mean values of nutritional indices of the 3rd, 4th, 5th and 6th instars of *Spodoptera littoralis* fed castor bean leaves treated with 100 mg $CdCl_2$/kg.

Instar \ Treatment	Control Mean ± SD	Cd Mean ± SD	(P) value
3rd instar			
CI	0.933 ± 0.092 a	0.609 ± 0.218 a	Ns
AD (%)	85.925 ± 2.001 a	89.414 ± 2.15 a	Ns
ECI (%)	20.828 ± 6.258 a	23.235 ± 1.964 a	Ns
ECD (%)	23.985 ± 6.35 5 a	28.93 ± 2.741 a	Ns
GR	0.185 ± 0.027 a	0.099 ± 0.018 b	0.013
4th instar			
CI	0.753 ± 0.002 a	0.406 ± 0.017 b	Hs
AD (%)	84.313 ± 1.012 a	84.607 ± 1.733 a	Ns
ECI (%)	24.205 ± 3.45 a	12.793 ± 1.848 b	0.004
ECD (%)	28.64 ± 3.5 a	12.747 ± 1.62 b	Hs
GR	0.182 ± 0.025 a	0.051 ± 0.006 b	Hs
5th instar			
CI	0.469 ± 0.011 a	0.278 ± 0.009 b	Hs
AD (%)	73.048 ± 2.851 a	65.278 ± 2.744 a	Ns
ECI (%)	32.118 ± 10.838 a	12.643 ± 1.031 b	0.008
ECD (%)	43.153 ± 7.11 a	22.548 ± 2.427 b	0.034
GR	0.153 ± 0.033 a	0.033 ± 0.004 b	0.012
6th instar			
CI	0.353 ± 0.033 a	0.233 ± 0.021 b	0.022
AD (%)	57.063 ± 2.33 a	32.938 ± 6.427 b	0.013
ECI (%)	20.865 ± 5.275 a	34.588 ± 1.059 a	Ns
ECD (%)	39.325 ± 5.742 a	19.153 ± 5.71 b	0.003
GR	0.245 ± 0.173 a	0.058 ± 0.007 a	Ns

- Means in rows followed by the same letters are significantly different ($P < 0.05$)
- Means in columns followed by the same letters are significantly different ($P < 0.05$)
- Ns: Not significant ($P > 0.05$), Hs: Highly significant ($P < 0.01$)

Similar to our results, BAGHBAN *et al.* (2014) found that under Cd-treatment, a probable damage to the epithelium of the gut of the noctuid moth; *Helicoverpa armigera* (Hübner, 1809) (Lepidoptera: Noctuidae) thereby; may hinder the absorption capacity.

Treatment with Cd significantly decreased ($P < 0.05$) the ECI compared the control at 4th and 5th instars (Table 1). On the contrary, significant increase in the values of ECI compared to the control was attained only at the 6th instar (Table 1). With advancing instars, there was a significant difference ($P < 0.05$) between 3rd and 4th, 3rd and 5th, 4th and 6th, and 5th and 6th instars (Table 1). EMRE *et al.* (2013) and BAGHBAN *et al.* (2014) attributed the increase in ECI under the stress of heavy metal treatment to the fact that insect requires a lot of energy to deal with the metal toxicity. This explanation may extend to our results.

The ECD at Cd-treatment significantly decreased ($P < 0.05$) at all the instars except the 3rd one (Table 1). Among the different instars, a significant difference ($P < 0.05$) was observed only between the 3rd and other instars (Table 1).

The growth rate was significantly decreased ($P < 0.05$) post-treatment with Cd at the 3rd, 4th, and 5th instars. Whereas, the change in GR was insignificant compared to the control at the 6th instar (Table 1). With advancing age, there was a significant difference ($P < 0.05$) between 6th and the remaining instars (Table 1). It has to be mentioned that high or moderate food consumption by insects is not always associated with high GR, as the latter might be affected by a low ECI value (WALDBAUER, 1968; MEHRKHOU, 2013). The decrease in GR in the present study may be accounted for by the decrease in CI and food utilization efficiencies expressed in terms of ECI and ECD. This suggestion is confirmed by the findings of WOODRING *et al*. (1978) who indicated that the amount of growth reduction was proportional in general to reduced food consumption. In agreement with our results, MIGULA *et al.* (1989) recorded reduced AD, ECI, and ECD in *Acheta domesticus* (Linnaeus, 1758) exposed to heavy metals.

In conclusion, it appears that exposure of *S. littoralis* larvae to Cd would reduce the weight gain. From practical standpoint, this finding may negatively impact the population dynamics of the next generation of this pest.

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