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CONTRIBUTION TO THE STUDIES OF THE INDIANMEAL MOTH *Plodia interpunctella* Hbn. (LEPIDOPTERA: PYRALIDAE) FECUNDITY DEPENDING ON DIET TYPE

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ABSTRACT. The study presented in this paper represents a preliminary experimental evaluation of fecundity of F_1 generation of Indianmeal moth, grown in ecological laboratory of Faculty of Scince in Kragujevac, depending on type of food offered to the larvae. Exactly five components of the standard laboratory diet were tested. The highest fecundity was registered in adults which as larvae were fed on wheat germs (137.26±3.98). Significantly lower fecundity (94.82±6.37) had the adults developed in the rolled oats, or whole wheat flour (66.04±7.94). The lowest average fecundity rate (only 49.29±6.6 eggs per pair) was registered for the adults grown on white cornmeal, while Brewers' yeast moths' cultures didn't produce F_1 adult generation at all. After comparation of the nutrient contents of four „succesful" diet types, we can conclude that the differences in the carb, fat and protein concentrations probably are crucial for the observed significant differences in the average *Plodia interpunctella* fecundity.

Key words: *Plodia interpunctella*, Kragujevac (Serbia), fecundity, diet type.

INTRODUCTION

Indianmeal moth, *Plodia interpunctella* (Hübner) from family Pyralidae (subfamily Phycitinae) is a major pest of stored food products (CUPERUS *et al*., 1990; DOUD and PHILLIPS, 2000; HINTON, 1943; LECATO, 1976; NANSEN *et al*., 2004; NANSEN and PHILLIPS, 2004; SEDLACEK *et al*., 1996; STOREY *et al*., 1983; VICK *et al*., 1986). It is possible that Indianmeal moth is the most important pest of stored, raw as well as processed human or animal food in the world. This moth species has very strong economic impact, because it uses a wide range of products in it's diet (LECATO, 1976; CLINE, 1978; STOREY *et al*., 1983; ALMAŠI, 1984; JOHNSON *et al*., 2002; SAUER and SHELTON, 2002; REES, 2004).

Indian meal moth is one of the most frequent and the most dangerous pest of stored grains in our country also (KRNJAJIĆ and ILIĆ, 1982). Many researchers already studied this moth in Serbia: STOJANOVIĆ (1955), VUKASOVIĆ *et al*. (1972), DOBRIVOJEVIĆ (1977), ILIĆ and VUKAJLOVIĆ (1981), KRNJAJIĆ and ILIĆ (1982), ALMAŠI (1984, 2008), ALMAŠI and STOJA-

NOVIĆ (1986), ALMAŠI *et al*. (1987), ALMAŠI and SRDIĆ (1988), ALMAŠI and VELJKOVIĆ (2006) etc.

Lifecycle of Indian meal moth could be completed in 30-days under optimal conditions, (REES, 2004). Development depends from the temperature (BELL, 1975; KRNJAJIĆ and ILIĆ, 1982; MBATA, 1985), as well as from the quality and quantity of food (ALMAŠI, 1984). The eggs hatch in around three days at 30°C. There are five (BAXTER, 2008) or seven (ALMAŠI, 1984) larval instars stages. Larvae of Indianmeal moth cause the most of food damages by secreting silky webs which permeate all substrat and contains larval feces and exuviae (ALMAŠI, 1984; FASULO and KNOX, 2008). Adult Indian meal moths do not feed (ALMAŠI and SRDIĆ, 1988), but can produce important number of descendants.

There are different data about number of laid eggs, starting from only 26 (ALMAŠI, 1984) on the wheat, through 96.8 (MOHANDASS *et al.*, 2007), i.e. 150-200 under optimal conditions during the crepuscular periods (REES, 2004), to the maximum of 400 eggs (FASULO and KNOX, 2008).

Fecundity is bigger when food sources are nuts, almonds or wheat bran (JOHNSON *et al*., 1992) than wheat or damaged corn seeds (ALMAŠI, 1984; ALMAŠI and STOJANOVIĆ, 1986; ALLOTEY and GOSWAMI, 1990).

The aim of our research was to study influence of larval diet on five selected food types (main components of the standard laboratory diet) on adult fecundity and to compare the results.

MATERIAL AND METHODS

Moth cultures

Cultures of Indian meal moth, established from the moths collected in the herbarium collection of Faculty of Science in Kragujevac, were reared in laboratory conditions, at 29±1°C and 60±5% r.h. in a thermostat chamber.

SILHACEK and MILLER (1972) published data about growth and development of the Indianmeal moth under laboratory mass-rearing conditions, in which they described standard laboratory diet (S.L.D.) for this moth. Based on their experimental data the standard laboratory diet contains white cornmeal (26%), whole wheat flour (23%), glycerol (16%), honey (14%), ground dog meal (10%), brewers' yeast (5%), rolled oats (4%) and wheat germs (2%).

Moths in our experiment were placed in 300 ml glass conical flasks with lid from the paper-wadding. There were 15 flasks (three for each food type), with 10 adults (five females and five males) in everyone. After developing of F_1 generation in thermostat chamber, adult moths were used in experiment.

Diet

Effects of five types of food source (elements of S.L.D.) were tested: wheat germs, rolled oats, white cornmeal, whole wheat flour and brewers' yeast. All of them were obtained from the local shop. Every glass conical flask (300 ml of volume) contained the same volume of food - 100 ml.

Experimental procedure

To estimate the fecundity of Indian meal moth, one pair of one-day-old F_1 adults was placed together with 15 cm long, 0.5 cm wide black paper tape into empty 25 ml glass test-tube and closed with paper-wadding lid covered with black plastic folio. Moths were allowed to lay eggs at temperature of 29±1°C, with a photoperiod of 14:10 (L:D) and 60-70% r.h, until female death. There were fifty replications for each food type. The total number of deposited eggs in the each test-tube was counted and used for the statistical analysis.

Statistical analysis

Statistical evaluation was calculated by one-way-ANOVA and Dunnett T3 test. For all comparisons, $p < 0.05$ was considered as significant.

RESULTS

Brewers' yeast Indian meal moths' cultures didn't produce the F_1 adult generation at all. This means that we haven't the opportunity to test the fecundity of this group of moths.

The wheat germs diet was superior comparing to all other analyzed food sources by the number of deposited eggs (fecundity). Moths reared on rolled oats followed it, while those reared on whole wheat flour have laid just a half eggs comparing with the first substratum. Rearing on white cornmeal resulted with smallest number of laid eggs (Table 1).

Table 1. - Mean fecundity per pair of *Plodia interpunctella* on four different diet types.

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower bound	Upper bound
Wheat germs	50	137.26	34.89	3.98	129.34	145.18
Rolled oats	50	94.82	36.61	6.37	81.84	107.80
White cornmeal	50	49.29	27.24	6.6	35.29	63.30
Whole wheat flour	50	66.04	42.02	7.94	49.74	82.33

One-way-ANOVA showed significant differences ($P<0.05$) among the four tested diet types. Dunnett's T3 test indicated that the mean difference is significant for almost all tested food types (Table 2).

The widest numerical oscillations between minimal and maximal fecundity per pair was registered among the moths reared on wheat germs. But proportion among these numbers shows opposite - it is only 3.6, while for rolled oats it is 9, for white cornmeal 8.8, and for the whole wheat flour the bigest 15.6.

DISCUSSION

In very rich literature there are many different data about dependance of Indian meal moth fecundity and diet type during their development. Results obtained in our experiments confirmed existance of differences in fecundity depending from the diet type already many times confirmed by other (ALMAŠI, 1984; ALMAŠI and STOJANOVIĆ, 1986; MOHANDASS *et al.*, 2007; JOHNSON *et al*., 1992; ALLOTEY and GOSWAMI, 1990; ARBOGAST, 2007).

Table 2. - Multiple comparasion of *Plodia interpunctella* fecundity per pair depending on different diet types done by Dunnett T3 test:
1-wheat germs, 2-rolled oats, 3-white cornmeal, 4-whole wheat flour.

Var. 1 (I)	Var. 2 (J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	42.44*	7.38	0.000	20.63	64.25
	3	87.97*	9.51	0.000	64.74	111.20
	4	71.22*	7.83	0.000	45.04	97.41
2	1	-42.44*	7.38	0.000	-64.25	-20.63
	3	45.52*	10.59	0.000	18.49	72.55
	4	28.78	9.12	0.063	-0.86	58.43
3	1	87.96*	9.51	0.000	-111.20	-64.74
	2	-45.52*	10.59	0.000	-72.55	-18.49
	4	-16.74	10.91	0.672	-47.12	13.64
4	1	-71.22*	7.83	0.000	-97.41	-45.04
	2	-28.78	9.12	0.063	-58.43	0.86
	3	16.74	10.91	0.672	-13.64	47.12

* The mean difference is significant at the 0.05 level.

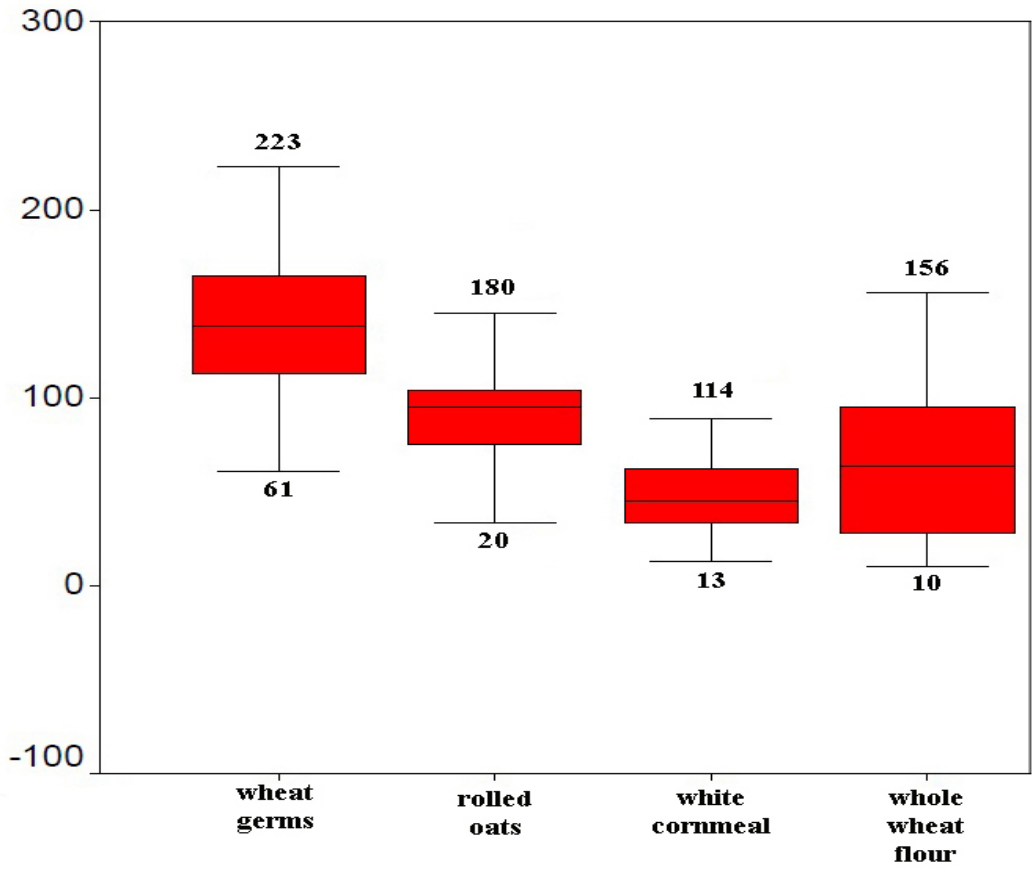

Fig. 1: Fecundity values of *Plodia interpunctella* reared on five different diet types. Values represent mean, lower and upper bound for mean interval as well as minimum and maximum values of fecundity.

It is important to make difference among the number of eggs formed into female reproductive organs and laid eggs. The second one is always less (ALMAŠI, 1984), but it is ecologicaly important.

The most comprehensive study on the effect of nutrition on fertility and number of generations of Indian meal moth in Serbia was done by ALMAŠI (1984). There were 43 food products tested (but neither one from „our“) and found that 86% of them were damaged by caterpillars. Among them the sunflower seeds showed the best results according to the fecundity. Number of layed eggs produced by females fed as caterpilars on these seeds was eight times bigger than those grown on wheat seeds. Explanation is simple - the caterpillars must collect (by eating) all necesary substances for the adults living, because adults do not feed at all (ALMAŠI and SRDIĆ, 1988).

Based on our preliminary experimental analysis as well as the literature data of the fecundity dependance on diet type we can make two main conclusions.

Wheat germs diet can be established as nutritionally most complete (Tab. 1, Fig. 1). This diet strongly supports the development of Indian meal moth. How important nutritive constituents of wheat germs are, ilustrate the fact that they participate with only 2 % in the composition of S.L.D. for *Plodia* (SILHACEK and MILLER, 1972). Particularlly good effects showed wheat germs glycerol- or glycerol/glucose-supplemented (SILHACEK and MURPHEY, 2006).

The most of earlier studies showed that wheat kernels are the worst choice of food for Indian meal moth (ALMAŠI, 1984). In our experiments whole wheat flour was penultimate according to the fecundity maybe because flour is easily adoptable for caterpilars than hard whole grains. However the biggest value of proportion among the minimal and maximal number of laid eggs for this diet confirmed it as not the most favorable for Indian meal moth.

For better understanding and explanation of fecundity results differences in dependance of feeding we have analized data about nutrient contents of used diets, ie. components of S.L.D. (wheat germs, roled oats, white cornmeal and whole weat flour), defined in the US Department of Agriculture Nutrient Database (NDB NO. 08084, 2012; NDB NO. 08122, 2012; NDB NO. 20080, 2012; NDB NO. 20320, 2012; respectively). It is clear distinction in the concentration of four of the most important groups of nutrients – carbs, proteins, fats and fibers. Obviously, the richest carbs content in white cornmeal doesn't have positive effect on mean fecundity (it is smallest), as well as range from minimal to maximal number of laid eggs (Fig. 1).

If we compare fat and protein contents among these four products (Fig. 2) – wheat germs are richest in both. The second conclusion after our experiments is that protein and fat concentration in caterpillar's diet is the most important for Indian meal moth fecundity. The concentrations of these substances, important for the oogenesis, are crucial for the registered significance in the mean Indianmeal moth's fecundity. Another illustration of importance of proteins and fats in Indian meal moth caterpillar diet are the facts that they, when are in the granary, first of all eat exactly the reproductive (germ) parts of seeds (ALMAŠI, 1984; SILHACEK and MURPHY, 2005).

This assumption is fully corresponding with the fact that female have already formed eggs during adult emerging from pupa (ALMAŠI and SRDIĆ, 1988). Except it, because adult do not feed at all, caterpillar must collect (by eating) in it's body all necesary substances for the adult's living (ALMAŠI and SRDIĆ, 1988).

Wheat germs are also a source of very important essential nutrients, such as Vitamin E, folic acid, phosphorus, thiamin, zinc, magnesium, essential fatty acids and fatty alcohols (COHEN, 2004), but these substances was not separately tested in our experiments. It could be subject of future studies.

Considering the fibers contents in four compared diet types, it is clean that their presence absolutelly follows proteins and fats and is adequate to mean fecundity values. Their presence in food generaly helps faster cleening of digestive system, and consequently better absorption of proteins and fats.

The future study of different Indian meal moth population's biology, particularly feeding and reproduction, could be helpful for its better biological control.

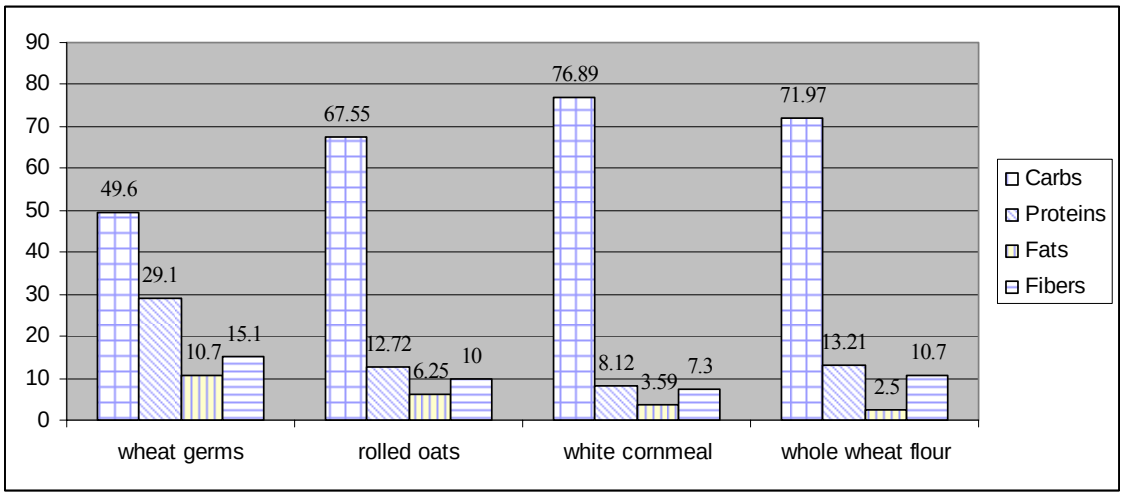

Figure 2. Comparative view of nutrients contents (four most important groups of nutrients) of wheat germs, rolled oats, white cornmeal and whole wheat flour (US Department of Agriculture Nutrient Database).

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