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Effects of moisture content of pistachio kernels on development and fecundity of Indian meal moth, *Plodia interpunctella* Hübner

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Abstract

Indian meal moth is one of the most important pests of stored products nearly in all around the world. Nowadays this insect is the most dangerous pest of stored dried pistachios in Iran. In order to determine the effects of moisture content of pistachio kernels on the growth and fecundity of Indian meal moth, insects were reared on five moisture treatments with different moisture levels of Badami pistachio cultivar and a control without any manipulation in its natural moisture. All experiments were conducted at laboratory conditions at 8:16 photoperiod, 25±1ºC temperature and 60±5% RH. Changes in moisture content of pistachio kernels were detected by means of sampling during the time of the experiment. The larvae of the Indian meal moth consumed pistachio kernels in all moisture treatments. Between treatments, adult moths that emerged at treatments with the highest moisture level (5.06±0.01%) showed the highest fecundity. In treatments with lower moisture levels (<5.06±0.01%) reduction in weight of female pupae and fecundity was recorded.

Keywords: Indian meal moth, moisture content, pistachio kernels, development, fecundity.

Introduction

Indian meal moth, *Plodia interpunctella* Hübner, is an important cosmopolitan pest that causes serious damages on many stored products such as grains, peanut, dried vegetables and dried pistachios (Bagheri, 1995; Bell, 1975; Esmaeli *et al.*, 1995; Johnson & Wofford, 1991). In recent years, it was considered as the most important pest of stored pistachios in Iran and that causes sever damages to quality and quantity of pistachio (Shojaaddini, 2004). In most regions of pistachio production, the use of fumigant chemicals such as

methyl bromide is the most common measure for controlling this pest. Due to harmful effects of chemicals on the health of human being and the environment, the detailed study of the bio-ecology of Indian meal moth have great importance, specially to find out useful non-chemical factors that can be used for the management of this major pest. Most studies about this pest were conducted on the non-chemical control methods such as using high and low temperatures (Jalilvand, 1996; Lewthwaite *et al.*, 1997; Mun & Ja, 1999; Sauer & Shelton, 2002), pheromone traps (Mullen & Arbogast, 1979) and change in photoperiod (Lum & Flaherty, 1970; Tsurumaki *et al.*, 1999). Different levels of moisture content in pistachio kernels can have various effects on growth and fecundity of Indian meal moth. Mbata & Osuji (1983) and Mbata (1986a,b) have conducted experiments on mating activities and commencement of oviposition also on the effects of groundnut moisture levels on some aspects of biology of Indian meal moth. Morrison & Williams (1998) have evaluated the effects of grain moisture content on the growth and fecundity of red fire ant. Bell (1975) investigated the effects of humidity on development of four pyralid moth pests of stored products.

The aim of this work was to compare the effects of different moisture levels of pistachio kernels on the growth and fecundity of the Indian meal moth in laboratory conditions.

Materials and Methods

In order to stop any infestation of arthropods, all pistachios were stored at -20ºC for 45 days. Due to moisture exchanges between kernels and surrounding atmosphere, any change in moisture content of kernels were measured and recorded during the experiment. This monitoring was conducted by means of a randomized sampling program on used kernels, every week. For this purpose, firstly, 5 random samples (5 kernels) were taken from each treatment. Then samples were weighted using a sensitive digital balance. Moisture content was calculated according to the function:

$$M = \frac{W - D}{W} \times 100,$$

where M is the moisture content (%), W the wet weight (mg), and D the dry weight (mg).

Moisture Treatments. According to the method described by UN Quality Standard for unshelled pistachio nuts (UNECE Standard DF-09), moisture percent of the pistachio kernels that were hold in oven with 103ºC temperature for 360 minutes, is regarded as 0%. Five groups of pistachio kernels were placed for 60, 120, 210, 270 and 360 minutes in a digital drying oven with increasing temperature from 25 to 103ºC. Control pistachios were not dried and had their natural moisture. Moisture percent of these five treatments were recorded through sampling and then converted into final experiment units (Tab. 1).

Table 1. Moisture treatments (A-E) by drying pistachios during five different times and a Control without any drying.

Treatments	Drying Time (Minute)	Moisture Content (Percent)
A	60	4.305
B	120	2.309
C	210	1.368
D	270	0.164
E	360	≈ 0.0
Control	0	5.065

Table 2. ANOVA of the effects of different moisture treatments on growth and fecundity of Indian meal moth.

Parameters	Mean square	Differences[1]	
		Statistic (df)	p-value
Weight of Male pupae	$2.327*10^{-6}$	1.099 (5,24)	0.395
Weight of Female pupae	$1.129*10^{-5}$	2.376 (5,24)	0.044*
Weight of male Adults	$1.020*10^{-6}$	2.149 (5,24)	0.106
Weight of Female adults	$1.435*10^{-5}$	2.870 (5,24)	0.037*
Survival of Male Adult	4.967	0.885 (5,24)	0.511
Survival of Female Adult	1.412	0.475 (5,24)	0.790
Male Larval Development	16.760	1.86 (5,24)	0.340
Female Larval Development	19.501	1.99 (5,24)	0.109
Mean of Egg Number	2040.006	3.320 (5,24)	0.020*

[1] Parameters with p-value less than 0.05 are marked with * (Statistical computer program: MSTATC version 1.42).

Table 3. Means (±SE) of weight of female pupae, weight of female adults and number of eggs laid by Indian meal moth.

Parameter	Treatments					
	A	B	C	D	E	Control
Weight of Female Pupae (mg.)	17±.6B	14.4±.3C	14.3±.1C	14.0±.1C	15.7±.1C	19.9±.1A
Weight of Adult Female (mg.)	6.9±.8B	4.9±.8C	4.5±.9C	4.4±.9C	3.6±.6D	8.1±.1A
Number of Eggs	77.33±14.8B	76.75±13.3B	56.66±20.2C	29.0±15.7D	26.33±11.5D	95.75±30.7A

Different letters indicate significant differences between treatments at $\alpha < 0.05$ (Statistical computer program: MSTATC version 1.42)

Indian meal moth Culture. Indian meal moth were taken from insect laboratory culture at Tabriz University, Iran, in 2004. Cultures were reared at 8:16 (Light:Dark), 25±1ºC and 60±5% RH. Larvae were fed on pistachio kernels from Badami cultivar with moisture content level at 5±0.01% in 250±10 ml hyaline plastic containers. Each container covered with a fine plastic mesh for good ventilation (Locatelli & Limonta, 1998). This culture was continued for 4 generations. Thirty pairs of virgin males and virgin females from the 5th generation were sexed and paired within one day after emerging and they were introduced in plastic cylinders for mating and oviposition.

Final Experiment. In a complete random design with 5 treatments and a control by 5 replications, 50 Indian meal moth eggs were placed into 150±10 ml plastic containers with fine mesh in their caps for ventilation. After 48 hours, the number of larvae was standardized to 30 first instar larvae in each unit. The containers were incubated at 8:16 (Light:Dark), 25±1ºC and 60±5% RH. Larval development times, weights of male and female pupae and adults were recorded through sampling from each treatment (5 samples per treatment). Adults were sexed and paired. Number of laid eggs and longevities of paired adults (days) were recorded.

Results

Monitoring the moisture content of pistachio kernels showed that the moisture level in treatment A and control have had minimum changes but treatment B, C, D and E have had respectively less to more changes in their moisture content (Fig. 1). Analysis of variances showed that different levels of moisture content had significant effects on weight of female pupae, weight of female adults and the number of eggs laid by females, but no significant effects observed on the larval development time, the weight of male pupae, nor the weight of male adults (Tab. 2).

Male adults emerged in control during the days 28 to 35 from the beginning of the experiment and showed a higher cumulative mean of adult emerged in early days of adult emerging, whereas in treatments emergence was from 29 to 42 days with relatively lower cumulative means (Fig. 2). Adult females emerged from day 30 to 43 and, compared to males, they showed differences between treatment and the control (Fig. 3). The results showed that the weight of both pupae and adult females within the control (mean 19.9 mg and 8.1 mg, respectively) were significantly higher than other treatments (Tab. 3). Fecundity as the number of eggs per female was significantly higher in control (98 eggs/female) and lower fecundity rates were observed in A, B, C, D and E treatments (Tab. 3).

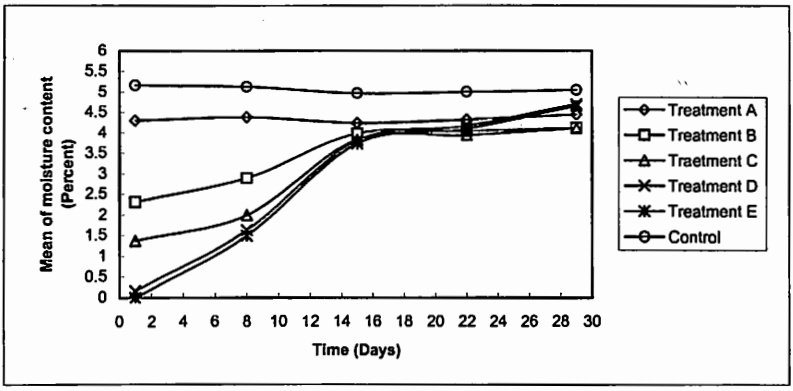

Fig. 1. The changes of moisture content of pistachio kernels in treatments during the time of experiment.

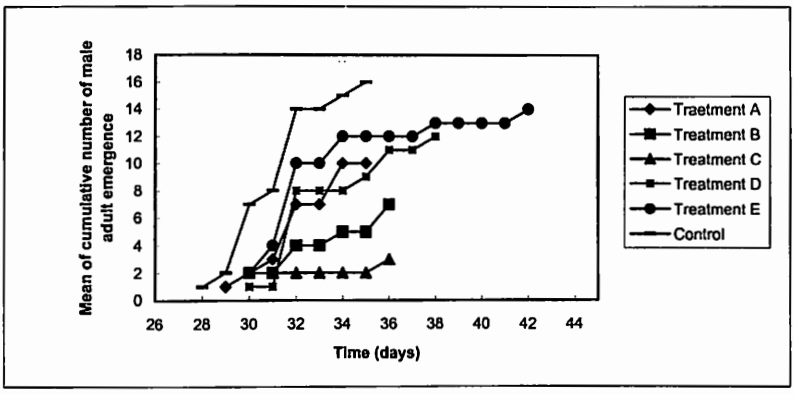

Fig. 2. The mean of cumulative number of male adults emerged in different treatments during the time of experiment.

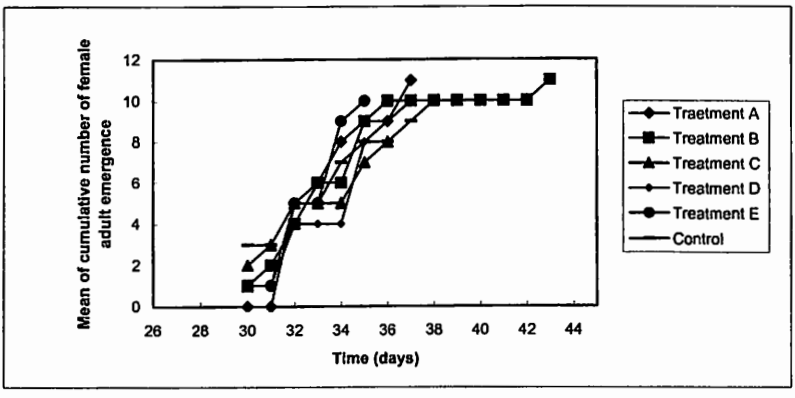

Fig. 3. The mean of cumulative number of female adults emerged in different treatments during the time of experiment.

Discussion

Not only the diet have much influence on the fecundity and fertility of Indian meal moth (Badawy, 1980; Salem *et al.*, 1980; Almasi *et al.*, 1987; Kivan & Karsavuran, 1991; Marzban, *et a*l., 2001) but also relative humidity (Bell, 1975; Mbata, 1986a) and moisture content of stored products (Morrison & Williams, 1998). The results of this study show that the fecundity decreased to a mean value of 26 (eggs/female) if the water content in the food is reduced down to zero but in the highest moisture level, the maximum fecundity was observed (95 eggs/female). Thus, extreme water reduction in the food reduced the population in the next generation. Also it has been shown that the damage of the red fire ant on grain seeds with higher moisture levels is 40 to 90 times as much as on dry seeds (Morrison & Williams, 1998). Mbata & Osuji, (1983) showed that groundnut moisture level has significant effects on the number of eggs laid by the Indian meal moth so that higher moisture contents could cause higher number of eggs per female adult. Since in the Indian meal moth, males and females are polygamous, females that receive smaller amounts of sperm do not exhibit reduced fertility, even at the end of their life (Cook, 1999). Therefore it is possible that the reduction in egg number results from change or degenerating oocytes in females (Lum, 1982; 1983). This experiment showed that low levels of moisture content in food material, even in partial time of experiment, had significant effects on fecundity of moths and the higher level of moisture content, the higher number of eggs laid by females (Tab. 3). This relation was true about weight of pupae and adults in females (Tab. 3). Larval development period and longevity of adult moths did not affected by different moisture treatments in neither males nor females (Tab. 2).

The moisture content of stored pistachio like most grains is not fixed and has a continuous exchange with the around atmosphere, so that there is an equilibrium between them. This equilibrium point varied among different seeds; seeds with higher contents of oil (e.g., sunflower, soybean, peanut and pistachio) do not absorb water as much as seeds with higher amounts of arch (e.g., wheat, corn and rice) (Chappell, 1954). This characteristic of pistachio kernels that have high percent of fatty acids (approximately 60%) has a great importance, because these kernels have good ability to keep their moisture content at low levels in comparison to other stored seeds.

In order to feed and develop, any organism such as an insect needs a certain range of moisture level in its food. For example, rice weevils need high moisture levels (more than 12%) and small grain beetles can survive in grains with low moisture levels (8-9%) and the other, most molds need moisture content more than 14-15% (Cuperus *et al.*, 1990). Water has many roles in insect body and keep a constant water balance have a great important. They needs to conserve water in order to compensate water losses. Insects and other arthropods have several mechanisms for getting water from their environment; most important ways are drinking, feeding wet food, absorbing water vapor from the atmosphere and producing metabolic water (Kerkut & Gilbert, 1985).

In an Integrated Pest Management program of the Indian meal moth, in the

pistachio warehouses, more attention should be paid to the factors influencing the growth and fecundity of this species (Mason, 1993). As shown by this study, moisture content of food is one ecological factor that significantly influences the development of the Indian meal moth. The results clearly show that the number of eggs decrease to a minimum extent if the water content in the food is reduced down to zero. In comparison, the maximum number of eggs per female is laid in the control. Thus, extreme water reduction in the food can be one factor chosen for the control of *P. interpunctella* in order to reduce the number of individuals in subsequent generations and therefore contribute to less damage of pistachios stored in warehouses. Since common methods of drying pistachios have no negative effects on either quality and flavor of stored pistachios (Lopez *et al.*, 1997; Kashani *et al.*, 2001; Ghazanfari *et al.*, 2002) it seems that this method in combination with keeping the relative humidity of warehouse at lower levels could be a suitable control mechanism for *P. interpunctella.*

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