J. Crop Prot. 2014, 3 (3): 295-304

Research Article

Feeding performance and some biological parameters of the Indian meal moth, *Plodia interpunctella* (Hübner) (Lepidoptera: Pyralidae) on artificial diets containing bran of different wheat cultivars

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Abstract: The eggs and larvae of the Indian meal moth, *Plodia interpunctella* (Hübner), are widely used in mass rearing of parasitoids and predators. Feeding indices and some biological parameters of *P. interpunctella* were studied on bran of different wheat cultivars ('Back-cross Roshan', 'Khooshe Pishgam', 'Khoshki line 9', 'Arg', 'Alvand', 'Pishtaz', 'WS-89-2', 'Sepahan' and 'Bam') when incorporated into artificial diets under laboratory conditions (25 ± 1 ºC, 65 ± 5% R.H., and a 16:8 h light-dark photoperiod). The efficiency of conversion of ingested food was highest on 'Back-cross Roshan' (98.79 ± 8.48%) and lowest on 'Pishtaz' (64.56 ± 9.66%). The highest and lowest percentage of mortality of *P. interpunctella* larvae were on 'Pishtaz' (56%) and 'Back cross Roshan' (12%). Our results showed that larval growth index was highest on 'Khoshki line 9' (5.81) and lowest on 'Pishtaz' (3.33). Moreover, the highest daily and total fecundity were detected in moths that were reared on 'Back-cross Roshan' (37.6 ± 0.93 and 177.3 ± 1.61 eggs, respectively). The results demonstrated that, among different wheat cultivars tested, 'Back-cross Roshan' was the most suitable cultivar for *P. interpunctella* rearing in order to optimize the mass production of natural enemies.

Keywords: Indian meal moth, feeding performance, biological parameters, bran of wheat

Introduction

The Indian meal moth, *Plodia interpunctella* (Hübner) (Lepidoptera: Pyralidae), is known as a major pest during the processing and storage of dried fruits including cereal, walnut, almond, pistachio and dates in Iran (Sepasgozarian, 1979) and other countries of the world (Azelmat *et al.,* 2005). Although this insect pest attacks more than one hundred stored products with different nutritional values and physical properties, the eggs and larvae of *P. interpunctella* have been used as alternative host to mass rearing of some predators and parasitoids, such as *Orius albidipennis* (Reuter) (Hemiptera: Anthocoridae) (Ghadamyari *et al.,* 2001), *Venturia canescens* (Gravenhorst) (Hymenoptera: Ichneumonidae) (Spanoudis and Andreadis, 2012), *Habrobracon hebetor* (Say) (Hymenoptera: Braconidae) (Akinkurolere *et al.,* 2009; Ghimire and Phillips, 2010) and *Trichogramma brassicae* (Bezdenko) (Hymenoptera: Trichogrammatidae) (Iranipour *et al.,* 2009), under laboratory conditions.

Developmental and physiological processes of insects can be affected by different factors such as temperature, humidity, photoperiod and the quality as well

Handling Editor: Dr. Azam Mikani

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Received: 6 August 2013, Accepted: 26 January 2014
Published online: 26 January 2014

[DOR: 20.1001.1.22519041.2014.3.3.15.4]

as the quantity of food (Johnson *et al.,* 1997; Na and Ryoo, 2000; Musa and Ren, 2005; Bouayad *et al.,* 2008).

The biology of *P. interpunctella* on various diets has been studied by several researchers. Arbogast (2007) evaluated the development of *P. interpunctella* immature stages under different temperature, humidity and dietary conditions. Bouayad *et al.* (2008) studied the effect of four diets (wheat flour, dates, sorghum and barely) on the post-embryonic development of this insect, and reported the shortest developmental time for the larvae reared on wheat flour. Biological characteristics of the Indian meal moth on three date cultivars were studied by Pourbehi *et al.* (2008), who observed the shortest developmental time of immature stages on cultivar Zahedi.

Although the bran of various wheat cultivars have different nutrients and are used incorporated with artificial diets for laboratory rearing of *P. interpunctella* (Silhacek and Miller, 1972), there are no published articles concerning feeding indices and biological aspects of this insect on various wheat cultivars. Therefore, this research was conducted to elucidate the feeding performance and some biological parameters of the Indian meal moth in response to feeding on artificial diets containing bran of nine wheat cultivars. The findings of this research would be useful to select the most suitable wheat cultivar for optimal feeding, rapid development, maximum survival and high fecundity of *P. interpunctella* in order to optimize the mass rearing of natural enemies in laboratory condition.

Materials and Methods

Artificial diet

Different wheat cultivars including 'Back-cross Roshan', 'Khooshe Pishgam', 'Khoshki line 9', 'Arg', 'Alvand', 'Pishtaz', 'WS-89-2', 'Sepahan' and 'Bam' were acquired from Agricultural and Natural Resources Research Center of Isfahan, Iran, and used to prepare artificial diets. For preparing dry part of artificial diet, 800 g of bran of various wheat cultivars and 160 g of brewer's yeast were mixed. For preparing aqueous part, 200 ml of honey and 200 ml of glycerol were dissolved and mixed. Then dry and liquid components were mixed, completely blended, and kept at room temperature for one week in closed containers (Silhacek and Miller, 1972).

Insect colony

Eggs of the Indian meal moth reared on an artificial diet (Silhacek and Miller, 1972) were obtained from Tarbiat Modares University (Tehran, Iran). The insects tested on different artificial diets prepared by the bran of various wheat cultivars had already been reared for two generations on the same diets under laboratory conditions (25 ± 1 ºC, 65 ± 5% R. H., and a 16:8 h light-dark photoperiod).

Feeding performance of *P. interpunctella*

Last instar larvae of *P. interpunctella* were weighed and transferred into plastic containers (diameter 16.5 cm, depth 7.5 cm) with a hole covered by a mesh net for ventilation, containing the artificial diet prepared by the bran of each tested cultivar. The weights of the larvae were daily recorded (before and after feeding) until they stopped feeding and reached the pre-pupal stage. The primary fresh foods and the foods remaining at the end of each experiment were daily weighed. The feces produced by the larvae were very low and mixed with food, so its amount was ignored.

The experiment was replicated five times, and each replication consisted of 15 last instar larvae. Feeding performance was calculated using formulae described by Waldbauer (1968); CI = consumption index, ECI = efficiency of conversion of ingested food, RCR = relative consumption rate, and RGR = relative growth rate.

[DOR: 20.1001.1.22519041.2014.3.3.15.4]

$$CI = \frac{E}{A}$$

$$ECI = \frac{P}{E}$$

$$RCR = \frac{E}{A * T}$$

$$RGR = \frac{P}{A * T}$$

where, A = mean weight of insect over unit time, E = weight of food consumed, P = weight gain of insect and T = duration of feeding period.

Larval mortality and growth indices of *P. interpunctella*

Percentage mortality of larvae, pupal weight (24 hours after pupation), larval growth index (LGI), standardized insect-growth index (SII) and fitness index (FI) of *P. interpunctella* were calculated on various artificial diets (Pretorius, 1976; Itoyama *et al.,* 1999):

$LGI = l_x/L$

$SII = P_w/L$

$FI = (P \times P_w)/(L + P_d)$

where, lx = survival rate of larvae, L = larval period, P_w = pupal weight, P = percentage of pupation and P_d = pupal period.

Oviposition period, longevity and fecundity of *P. interpunctella*

After emergence of adult moths, a pair of female and male was transferred to egg-laying containers (11.5 cm in diameter and 9.5 cm in height), closed at the top with a fine mesh net for aeration. The egg-laying containers were then inversely placed on the paper sheets (as an oviposition surface) and the number of eggs deposited was daily collected and counted. In the current study, pre-oviposition and oviposition periods, adult longevity, daily fecundity (eggs/reproduction day) and total fecundity (eggs during the reproductive period) of *P. interpunctella* were recorded on various artificial diets until the death of the last moth.

Data analysis

Feeding performance and biological aspects of *P. interpunctella* reared on different artificial diets were analyzed with one-way ANOVA followed by comparison of the means with LSD test at α = 0.05 using statistical software Minitab 16.0. All data were tested for normality before analysis. A dendrogram of feeding performance and biological parameters of *P. interpunctella* on different artificial diets was created after cluster analysis by Ward's method using SPSS 16.0 statistical software.

Results

Feeding performance of *P. interpunctella*

The results of the feeding performance of *P. interpunctella* last instar larvae are shown in Table 1. The highest weight was recorded for the last instar larvae fed on 'Bam' ($F = 25.43$; $df = 8, 35$; $P < 0.01$) while the lowest weight was recorded for larvae reared on 'Khoshki line 9'. The highest and lowest amounts of food consumed ($F = 8.10$; $df = 8, 36$; $P < 0.01$) were observed in the larvae fed on cultivars 'Khooshe Pishgam' and 'WS-89-2', respectively. The highest and lowest values of larval weight gain ($F = 5.56$; $df = 8, 35$; $P < 0.01$) were on 'Khoshki line 9' and 'WS-89-2', respectively. The highest and lowest values of consumption index ($F = 14.6$; $df = 8, 33$; $P < 0.01$) were on 'Khoshki line 9' and 'WS-89-2', respectively. The efficiency of conversion of ingested food ($F = 0.63$; $df = 8, 35$; $P < 0.01$) was highest on 'Back-cross Roshan' and lowest on 'Pishtaz'. The larvae fed on 'Khooshe Pishgam' and 'WS-89-2' showed respectively the highest and lowest values of relative consumption rate ($F = 11.97$; $df = 8, 35$; $P < 0.01$). Moreover, the highest value of relative growth rate ($F = 19.93$; $df = 8, 34$; $P < 0.01$) was on 'Khooshe Pishgam' and lowest was on 'WS-89-2'.

Larval mortality and growth indices of *P. interpunctella*

The highest and lowest percentage mortality of *P. interpunctella* larvae were on 'Pishtaz' and

[DOR: 20.1001.1.22519041.2014.3.3.15.4]

'Back cross Roshan', respectively (Table 2). Our results showed that the highest and lowest values of larval growth index were on 'Khoshki line 9' and 'Pishtaz', respectively. The standardized insect-growth index of the Indian meal moth was not significantly different on various artificial diets. The highest pupal weight ($F = 21.77$; df = 8, 36; $P < 0.01$) was on 'WS-89-2', and the lowest was on 'Alvand'. Moreover, the highest value of fitness index ($F = 70.51$; df = 8, 36; $P < 0.01$) was on 'Arg', and the lowest was on 'Alvand'.

Oviposition period, longevity and fecundity of *P. interpunctella*

Oviposition period, longevity and fecundity of *P. interpunctella* adults emerged from the larvae reared on different artificial diets containing bran of various wheat cultivars are shown in Table 3. There was no significant difference in the pre-oviposition period of *P. interpunctella* on different artificial diets, however, the longest oviposition period ($F = 6.01$; df = 8, 36; $P < 0.01$) of this insect was on 'Back cross Roshan'. The male and female longevity of *P. interpunctella* ($F = 10.20$; df = 8, 36; $P < 0.01$) was longest on 'Back cross Roshan' and shortest on 'Arg'. The daily fecundity ($F = 74.61$; df = 8, 36; $P < 0.01$) was highest on 'Back cross Roshan' and lowest on 'Khooshe Pishgam'. The highest and lowest total fecundity ($F = 412.77$; df = 8, 36; $P < 0.01$) were on 'Back cross Roshan' and 'Pishtaz', respectively (Table 3).

Table 1 Feeding performance of the last instar larvae of *Plodia interpunctella* fed on artificial diets containing bran of various wheat cultivars.

Wheat cultivars	Weight/Larva (g)	Consumed food (g)	Weight gained/larva (g)	CI [a]	ECI [b] (%)	RCR [c] (g/g/day)	RGR [d] (g/g/day)
'Back cross Roshan'	0.0077de (± 0.0020)	0.0020cd (± 0.0009)	0.0019cde (± 0.0009)	0.14ef (± 0.06)	98.79a (± 8.48)	0.022cd (± 0.011)	0.021cd (± 0.011)
'Khooshe Pishgam'	0.0072de (± 0.0005)	0.0064a (± 0.0010)	0.0047ab (± 0.0002)	0.83b (± 0.13)	72.1ab (± 15.7)	0.230a (± 0.051)	0.191a (± 0.029)
'Khoshki line 9'	0.0052e (± 0.0003)	0.0063a (± 0.0008)	0.0053a (± 0.0008)	1.31a (± 0.23)	82.62ab (± 8.27)	0.112b (± 0.023)	0.073b (± 0.009)
'Arg'	0.0106bc (± 0.0007)	0.0006d (± 0.0008)	0.0044ab (± 0.0010)	0.56bc (± 0.09)	73.1ab (± 11.0)	0.038cd (± 0.006)	0.028cd (± 0.007)
'Alvand'	0.0090cd (± 0.0007)	0.0042abc (± 0.0005)	0.0029bcd (± 0.0005)	0.53cd (± 0.02)	68.7b (± 6.25)	0.031cd (± 0.001)	0.019cd (± 0.003)
'Pishtaz'	0.0062e (± 0.0010)	0.0024bcd (± 0.0002)	0.0015de (± 0.0002)	0.42cde (± 0.06)	64.56b (± 9.66)	0.075bc (± 0.025)	0.047bc (± 0.018)
'WS-89-2'	0.0120b (± 0.0008)	0.0005d (± 0.0001)	0.0004e (± 0.0001)	0.04f (± 0.01)	82.94ab (± 6.03)	0.003d (± 0.001)	0.002d (± 0.0001)
'Sepahan'	0.0172a (± 0.0005)	0.0024bcd (± 0.0003)	0.0021cde (± 0.0003)	0.14ef (± 0.016)	86.33ab (± 1.67)	0.008d (± 0.001)	0.007d (± 0.001)
'Bam'	0.0180a (± 0.0003)	0.0044ab (± 0.0012)	0.0034bc (± 0.0011)	0.24def (± 0.07)	67.8b (± 16.0)	0.013d (± 0.004)	0.010cd (± 0.003)

The means (± SE) followed by different letters in the same column are significantly different (LSD, $P < 0.01$).
[a] Consumption index
[b] Efficiency of conversion of ingested food
[c] Relative consumption rate
[d] Relative growth rate

[DOR: 20.1001.1.22519041.2014.3.3.15.4]

Table 2 Mortality rate (%), larval growth index (LGI), standardized insect-growth index (SII), pupal weight (g) and fitness index of *Plodia interpunctella* on artificial diets containing bran of various wheat cultivars.

Wheat cultivars	Larval mortality (%)	LGI	SII (g/day)	Pupal weight (g)	Fitness index (g/day)
'Back cross Roshan'	12	4.19	0.92 ± 0.05a	0.024 ± 0.004ab	0.042 ± 0.002bc
'Khooshe Pishgam'	17	4.82	0. 94 ± 0.05a	0.019 ± 0.002c	0.043 ± 0.001b
'Khoshki line 9'	18	5.81	0.90 ± 0.21a	0.010 ± 0.001e	0.030 ± 0.002d
'Arg'	23	4.50	0.82 ± 0.03a	0.021 ± 0.001bc	0.056 ± 0.002a
'Alvand'	19	5.78	0.90 ± 0.01a	0.004 ± 0.001f	0.006 ± 0.001e
'Pishtaz'	56	3.33	1.08 ± 0.03a	0.019 ± 0.001c	0.030 ± 0.002d
'WS-89-2'	26	4.12	0.92 ± 0.04a	0.026 ± 0.001a	0.044 ± 0.002b
'Sepahan'	18	4.53	0.94 ± 0.05a	0.014 ± 0.001de	0.030 ± 0.001d
'Bam'	37	4.20	1.02 ± 0.05a	0.017 ± 0.001cd	0.038 ± 0.001c

The means (± SE) followed by different letters in each column are significantly different (LSD, $P < 0.01$).

Table 3 Oviposition period (day), longevity (day), daily and total fecundity (egg) of *Plodia interpunctella* on artificial diets containing bran of various wheat cultivars.

Wheat cultivars	Pre-oviposition period	Oviposition period	Male longevity	Female longevity	Daily fecundity	Total fecundity
'Back cross Roshan'	2.8 ± 0.37a	7.6 ± 0.51a	9.0 ± 0.44a	9.2 ± 0.24a	37.6 ± 0.93a	177.3 ± 1.61a
'Khooshe Pishgam'	3.8 ± 0.37a	4.6 ± 0.51b	7.2 ± 0.37b	7.5 ± 0.42b	13.6 ± 1.54g	157.1 ± 1.99c
'Khoshki line 9'	2.8 ± 0.37a	5.0 ± 0.32b	7.8 ± 0.37b	7.2 ± 0.32b	21.0 ± 0.45de	143.4 ± 1.89d
'Arg'	3.4 ± 0.51a	5.2 ± 0.37b	5.0 ± 0.40d	4.8 ± 0.38d	25.6 ± 0.68c	126.9 ± 1.08f
'Alvand'	3.4 ± 0.25a	4.6 ± 0.40b	6.0 ± 0.31cd	6.2 ± 0.29cd	26.6 ± 1.03c	164.7 ± 0.47b
'Pishtaz'	3.6 ± 0.40a	4.6 ± 0.40b	5.6 ± 0.40d	5.4 ± 0.38d	18.8 ± 1.16ef	99.1 ± 0.64g
'WS-89-2'	3.4 ± 0.25a	5.0 ± 0.32b	5.6 ± 0.40d	5.0 ± 0.32d	32.6 ± 0.51b	165.2 ± 1.08b
'Sepahan'	2.8 ± 0.37a	4.8 ± 0.37b	7.0 ± 0.32bc	6.8 ± 0.30bc	17.8 ± 0.37f	123.7 ± 0.42f
'Bam'	4.4 ± 0.51a	4.6 ± 0.25b	6.0 ± 0.31cd	5.9 ± 0.34cd	22.8 ± 0.37d	133.7 ± 0.53e

The means (± SE) followed by different letters in each column are significantly different (LSD, $P < 0.01$).

Cluster analysis

Figure 1 demonstrates the dendrogram of various wheat cultivars resulted from cluster analysis of feeding performance and some biological parameters of *P. interpunctella*. The dendrogram indicated three clusters labelled A, B and C. Various cultivars were grouped within each cluster based on the comparative feeding performance, and some biological aspects of *P. interpunctella* fed on these cultivars. Cluster A consisted of cultivars 'Sepahan', 'Bam', 'WS-89-2' and 'Pishtaz'; cluster B included 'Khooshe Pishgam', 'Arg', 'Khoshki line 9' and 'Alvand' and cluster C consisted of 'Back cross Roshan'.

Discussion

Plodia interpunctella larvae are known to be able to develop on a great number of food resources, and their development is largely

[DOR: 20.1001.1.22519041.2014.3.3.15.4]

influenced by the quality of food (LeCato, 1976; Bouayad *et al.,* 2008). In this study, we showed that the artificial diets containing bran of various wheat cultivars had significant effect not only on the physiological characteristics (i. e. feeding performance) of the Indian meal moth, but also on some biological aspects of this insect.

The significant differences among feeding performance of the last instar larvae of *P. interpunctella* on the bran of nine wheat cultivars indicated that the cultivars tested had different nutritional values. The highest and lowest values of larval weight were respectively on 'Bam' and 'Khoshki line 9'. Sarate *et al.* (2012) noted that the lepidopteran larvae fed on diets rich in protein demonstrate higher body weight. Accordingly, the artificial diet containing bran of cultivar 'Bam' probably was rich in protein. The highest larval weight of *P. interpunctella* on 'Bam' is 15-fold lower than that reported by Borzouei (2012) for the Indian meal moth on artificial diet (containing wheat bran, yeast, honey and glycerol). Possible reason for this discrepancy can be because of the variations of wheat cultivars, genetic differences as a result of laboratory rearing or variation in strains of *P. interpunctella.*

In the insects, amount of food consumed (FC) is one of the main features affecting digestive enzymatic activity responsible for supplying energy to the growing larvae (Sivakumar *et al.,* 2006). In the current study, we observed the lowest FC on 'WS-89-2', indicating that the larvae fed on this cultivar had the lowest weight gain and digestive activity as compared to the others. The results showed that the *P. interpunctella* larvae reared on 'Khoshki line 9' had the highest value of CI, suggesting that the larvae fed on this cultivar had the highest rate of intake relative to the mean larval weight during the feeding period. The index ECI is a measure of an insect's ability to incorporate ingested food into growth (Nathan *et al.,* 2005). Among the tested artificial diets, the ECI value of the last instar larvae was the highest on 'Back cross Roshan' cultivar, demonstrating that the larvae fed on this cultivar were more efficient at converting ingested food to body biomass. The lowest ECI value of *P. interpunctella* last instar larvae on 'Pishtaz' may have resulted from the low efficiency in converting ingested food into growth.

Overall, lepidopteran larvae fed on a high-nutrient diet, increase rates of the growth and complete the development period faster than those fed on low-nutrient diet (Hwang *et al.,* 2008). The duration of feeding period is an effective factor in the RGR and RCR values. The lowest RCR value in the larvae fed on 'WS-89-2' can probably be correlated with longer feeding period of the last instar larvae on this cultivar. Our results showed that the RGR value was lowest on 'WS-89-2'. This could be due to either decreased consumption rate or extension of larval period when the amount of ingested food was increased. Another reason for this reduction may be correlated with the lower weight gain of the larvae fed on this cultivar. The highest RGR value on 'Khooshe Pishgam' might be attributed to the highest relative consumption rate on this cultivar.

The lowest larval mortality on 'Back cross Roshan' (12%) is similar to that reported by Sarate *et al.* (2012) for *H. armigera* larvae fed on the artificial diet (12%). Our results also showed that the highest larval growth index (LGI) was in the larvae fed on 'Khoshki line 9', which can be correlated with a higher survival rate and shorter larval period on this cultivar. Since the highest rate of larval mortality was in the larvae fed on 'Pishtaz', the lowest value of LGI was detected on this cultivar, suggesting that the artificial diet containing 'Pishtaz' is an unsuitable diet for the growth and survival of the larvae. It is accepted that the pupal weight is an indicator of lepidopteran fitness and that can easily be measured (Leuck and Perkins, 1972). The larvae of *P. interpunctella* fed on 'Alvand' had the lightest pupal weight as compared to those reared on other wheat cultivars, suggesting that 'Alvand' was unsuitable diet for *P. interpunctella* larvae than the others. The highest fitness index in the larvae fed on 'Arg' can probably be attributed with a higher percentage of pupation or higher pupal weight on this cultivar.

[DOR: 20.1001.1.22519041.2014.3.3.15.4]

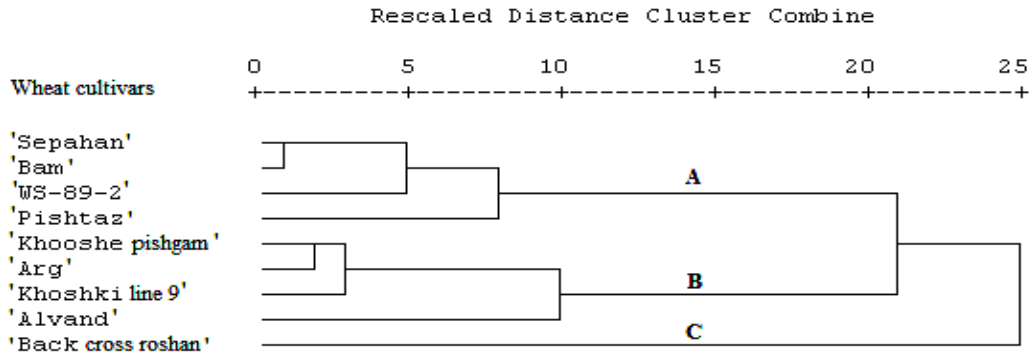

Figure 1 Dendrogram of artificial diets containing the bran of various wheat cultivars according to feeding performance and some biological parameters of *Plodia interpunctella* on the tested cultivars (Ward's method).

In agreement with the other works (Arbogast, 2007; Shayesteh *et al.,* 2010), we found that the male and female longevity of the Indian meal moth was significantly influenced by the different diets. The longest male and female longevity of the Indian meal moth on 'Back cross Roshan' is a little longer than the longevity of *P. interpunctella* on three date cultivars (Zahedi, Shahabi and Kabkab) (Pourbehi *et al.,* 2010). This variation can be due to the difference between the host diets and variation in the strain of examined insect species.

The food source is an important factor for determining fecundity, and the fecundity of moths can be influenced by different diets (Mbata, 1985; Shayesteh *et al.,* 2010; Fathipour and Naseri, 2011; Madboni and Pour Abad, 2012). The highest daily fecundity in females emerged from the larvae fed on 'Back cross Roshan' can be due to the longest longevity of the female on this cultivar.

In our research, the larvae fed on cultivar 'Back cross Roshan' and 'Pishtaz' showed respectively the highest and lowest levels of total fecundity. The highest total fecundity on 'Back cross Roshan' is nearly similar to that reported for *P. interpunctella* reared on broken maize (Allotey and Goswami, 1990), and on dates cultivar Zahedi (a suitable cultivar) (Pourbehi *et al.,* 2010), indicating that these diets have probably similar nutritional values for the insect reproduction. However, this value is 1.5-fold lower than that reported by Allotey and Goswami (1990) for the Indian meal moth reared on wheat bran. The possible reason for this discrepancy might be due to the variations in nutritive values of wheat cultivars and/or differences in strains of *P. interpunctella.*

The results of the cluster analysis showed that grouping within each cluster might be due to a high level of physiological similarity of various wheat cultivars. The results demonstrated that 'Sepahan', 'Bam', 'WS-89-2', and 'Pishtaz' were unsuitable cultivars, while 'Back cross Roshan' was the most suitable cultivar for feeding and rearing of *P. interpunctella*. Cultivars 'Khooshe Pishgam', 'Arg', 'Khoshki line 9' and 'Alvand' had an intermediate status. The observed differences could be because of differences in either cultivar quality or nutrients needed by the insect (Arbogast, 2007; Bouayad *et al.,* 2008).

Since *P. interpunctella* is a suitable alternative host for mass rearing of some predators and parasitoids (Ferkovich and Shapiro, 2004; Ghimire and Phillips, 2010; Spanoudis and Andreadis, 2012), thus, optimizing the mass rearing of this insect on the artificial diets would economically be useful. By combining the results from the current study regarding feeding performance and biological aspects of the Indian meal moth on the bran of various wheat cultivars,

[DOR: 20.1001.1.22519041.2014.3.3.15.4]

we found the highest daily and total fecundity, longest oviposition period, male and female longevity as well as the highest levels of ECI in the larvae fed on 'Back cross Roshan', suggesting that among different cultivars, this cultivar is the most suitable host for preparing artificial diet for rearing of *P. interpunctella*.

Acknowledgements

We would like to thank F. Rahimi Namin and Z. Golparvar (from University of Mohaghegh Ardabili) for their valuable assistance in this research.

References

Akinkurolere, R. O., Boyer, S., Chen, H. and Zhang, H. 2009. Parasitism and host-location preference in *Habrobracon hebetor* (Hymenoptera: Braconidae): role of refuge, choice, and host instar. Journal of Economic Entomology, 102 (2): 610-615.

Allotey, J. and Goswami, L. 1990. Comparative biology of two phyctid moths, *Plodia interpunctella* (Hübn.) and *Ephestia cautella* (Wlk.) on some selected food media. Insect Science and its Application, 11: 209-215.

Arbogast, R. T. 2007. A wild strain of *Plodia interpunctella* (Hübner) (Lepidoptera: Pyralidae) from farm-stored maize in South Carolina: development under different temperature, moisture, and dietary conditions. Journal of Stored Products Research, 43: 160-166.

Azelmat, K., Sayah, F., Mouhib, M., Ghailani, N. and Elgarrouj, D. 2005. Effects of gamma irradiation on fourth-instar *Plodia interpunctella* Hübner (Lepidoptera: Pyralidae). Journal of Stored Products Research, 41: 423-431.

Borzouei, E. 2012. Comparative effects of some diets on amylase and protease activity in Indian meal moth, *Plodia interpunctella.* MSc thesis, University of Tehran, Tehran. 108 pp.

Bouayad, N., Rharrabe, K., Ghilani, N. and Sayah, F. 2008. Effects of different food commodities on larval development and α-amylase activity of *Plodia interpunctella* (Hübner) (Lepidoptera: Pyralidae). Journal of Stored Products Research, 44: 373-378

Fathipour, Y. and Naseri, B. 2011. Soybean cultivars affecting performance of *Helicoverpa armigera* (Lepidoptera: Noctuidae), In: Ng, T. B. (Ed.), Soybean - Biochemistry, Chemistry and Physiology. 642 pp. In Tech, Rijeka, Croatia, pp. 599-630.

Ferkovich, S. M. and Shapiro, J. P. 2004. Comparison of prey-derived and non-insect supplements on egg-laying of *Orius insidiosus* maintained on artificial diet as adults. Biological Control, 31: 57-64.

Ghadamyari, M., Talebi, K. H., Rasooliyan, Gh. R. and Hosseini, S. M. 2001. Evaluation of several diets in rearing of *Orius albidipennis* Reut. (Het.: Anthocoridae). Journal of Agriculture Sciences, 7 (1): 31-42.

Ghimire, M. N. and Phillips, T. W. 2010. Mass rearing of *Habrobracon hebetor* Say (Hymenoptera: Braconidae) on larvae of the Indian meal moth, *Plodia interpunctella* (Lepidoptera: Pyralidae): effects of host density, parasitoid density, and rearing containers. Journal of Stored Products Research, 46 (4): 214-220.

Hwang, S. Y., Liu, C. H. and Shen, T. C. 2008. Effects of plant nutrient availability and host plant species on the performance of two *Pieris* butterflies (Lepidoptera: Pieridae). Biochemical Systematics and Ecology, 36: 505-513.

Iranipour, S., Farazmand, A., Saber, M. and Mashhadi, J. M. 2009. Demography and life history of the egg parasitoid, *Trichogramma brassicae,* on two moths *Anagasta kuehniella* and *Plodia interpunctella* in the laboratory. Journal of Insect Science, 9 (51), available online: inectscience.org/9.51.

Itoyama, K., Kawahira, Y., Murata, M. and Tojo, S. 1999. Fluctuations of some characteristics in the common cutworm, *Spodoptera litura* (Lepidoptera: Noctuidae) reared under different diets. Applied Entomology and Zoology, 34: 315-321.

Johnson, J. A., Valero, K. A. and Hannel, M. M. 1997. Effect of low temperature storage on survival and reproduction of Indian meal

[DOR: 20.1001.1.22519041.2014.3.3.15.4]

moth (Lepidoptera: Pyralidae). Crop Protection, 16: 519-523.

LeCato, G. L. 1976. Yield, development, and weight of *Cadra cautella* (Walker) and *Plodia interpunctella* (Hübner) on twenty-one diets derived from natural products. Journal of Stored Products Research, 12: 43-47.

Leuck, D. B. and Perkins, W. D. 1972. A method of evaluating fall armyworm progeny reduction when evaluating control achieved by host plant resistance. Journal of Economic Entomology, 65: 482-483.

Madboni, M. A. Z. and Pour Abad, R. F. 2012. Effect of different wheat varieties on some of developmental parameters of *Anagasta kuehniella* (Lepidoptera: Pyralidae). Munis Entomology and Zoology, 7 (2): 1017-1022.

Mbata, G. N. 1985. Some physical and biological factors affecting oviposition by *Plodia interpunctella* (Hübner) (Lepidoptera: Phycitidae). Insect Science and its Application, 6: 597-604.

Musa, P. D. and Ren, S. X. 2005. Development and reproduction of *Bemisia tabaci* (Homoptera: Aleyrodidae) on three bean species. Insect Science, 12: 25-30.

Na, J. H. and Ryoo, M. I. 2000. The influence of temperature on development of *Plodia interpunctella* (Lepidoptera: Pyralidae) on dried vegetable commodities. Journal of Stored Products Research, 36: 125-129.

Nathan, S. S., Chung, P. G. and Murugan, K. 2005. Effect of biopesticides applied separately or together on nutritional indices of the rice leafolder *Cnaphalocrocis medinalis*. Phytoparasitica, 33: 187-195.

Pourbehi, H., Talebi, A. A., Zamani, A. A., Goldasteh, Sh. and Farrar, N. 2010. Comparison of the biological characteristics of the *Plodia interpunctella* Hübner (Lep., Pyralidae) on three date cultivars in laboratory conditions. Journal of Entomological Research 1 (4): 279-288. [In Persian with English summary].

Pretorius, L. M. 1976. Laboratory studies on the developmental reproductive performance of *Helicoverpa armigera* on various food plants. Journal of the Entomological Society of Southern Africa, 39: 337-334.

Sarate, P. J., Tamhane, V. A., Kotkar, H. M., Ratnakaran, N., Susan, N., Gupta, V. S. and Giri, A. P. 2012. Developmental and digestive flexibilities in the midgut of a polyphagous pest, the cotton bollworm, *Helicoverpa armigera*. Journal of Insect Science, 42 (12), available online: insectscience.org/12.42.

Sepasgozarian, H. 1979. Stored pests of Iran and their control. University of Tehran Publications, Tehran.

Shayesteh, N., Marouf, A. and Amir-Maafi, M. 2010. Some biological characteristics of the *Batrachedra amydraula* Meyrick (Lepidoptera: Batrachedridae) on main varieties of dry and semi-dry date palm in Iran. Proceedings of 10th International Working Conference on Stored Product Protection, Estoril, Portugal, p. 151-155.

Silhacek, D. L. and Miller, G. L. 1972. Growth and development of the Indian meal moth, *Plodia interpunctella* (Lepidoptera: Phycitidae) under laboratory mass-rearing conditions. Annals of the Entomological Society of America, 65: 1084-1087.

Sivakumar, S., Mohan, M., Franco, O. L. and Thayumanavan, B. 2006. Inhibition of insect pest α-amylases by little and winger millet inhibitors. Pesticide Biochemistry and Physiology, 85: 155-160.

Spanoudis, Ch. G. and Andreadis, S. S. 2012. Temperature-dependent survival, development, and adult longevity of koinobiont endoparasitoid *Venturia canescens* (Hymenoptera: Ichneumonidae) parasitizing *Plodia interpunctella* (Lepidoptera: Pyralidae). Journal of Pest Science, 85 (1): 75-80.

Waldbauer, G. P. 1968. The consumption and utilization of food by insects. Advances in Insect Physiology, 5: 229-288.

[DOR: 20.1001.1.22519041.2014.3.3.15.4]

کارایی تغذیه‌ای و برخی پارامترهای زیستی شب‌پره هندی *Plodia interpunctella* (Hübner) (Lep.: Pyralidae) روی غذای مصنوعی تهیه شده با سبوس ارقام مختلف گندم

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چکیده: تخم‌ها و لاروهای شب پره‌ی هندی، *Plodia interpunctella* (Hübner)، به‌عنوان میزبان جایگزین در پروش انبوه پارازیتوئیدها و شکارگرها مورد استفاده قرار می‌گیرند. شاخص‌های تغذیه‌ای و برخی پارامترهای زیستی *P. interpunctella* روی سبوس ارقام مختلف گندم ('Back cross Roshan'، 'Khooshe Pishgam'، 'Khoshki line 9'، 'Arg'، 'Alvand'، 'Pishtaz'، 'WS-89-2'، 'Sepahan' و 'Bam') در قالب رژیم غذایی مصنوعی تحت شرایط آزمایشگاهی (دمای ۱± ۲۵ درجه‌ی سلسیوس، رطوبت نسبی ۵ ± ۶۵ درصد و دوره‌ی نوری ۱۶ ساعت روشنایی و ۸ ساعت تاریکی) مطالعه شد. بیشترین کارایی تبدیل غذای خورده شده روی رقم 'Back cross Roshan' (۸/۴۸ ± ۹۸/۷۹ درصد) و کمترین آن روی رقم 'Pishtaz' (۹/۶۶ ± ۶۴/۵۶ درصد) بود. بیشترین و کمترین درصد مرگ‌ومیر لاروهای *P. interpunctella* روی 'Pishtaz' (۵۶ درصد) و 'Back cross Roshan' (۱۲ درصد) بود. نتایج نشان داد که شاخص رشد لاروی روی 'Khoshki line 9' بیشترین (۵/۸۱) و روی 'Pishtaz' (۳/۳۳) کمترین بود. ببیشترین باروری روزانه و باروری کل روی رقم 'Back cross Roshan' (به‌ترتیب ۰/۹۳ ± ۳۷/۶ و ۱/۶۱ ± ۱۷۷/۳ تخم) مشاهده شد. نتایج نشان داد که در میان ارقام مختلف گندم مورد مطالعه، رقم 'Back cross Roshan' مناسب‌ترین رقم برای پرورش *P. interpunctella* به‌منظور بهینه‌سازی تولید انبوه دشمنان طبیعی بود.

واژگان کلیدی: شب پره‌ی هندی، کارایی تغذیه‌ای، پارامترهای زیستی، سبوس گندم

[DOR: 20.1001.1.22519041.2014.3.3.15.4]