The attractiveness of moth webbings in the cone traps placed in grain on the females confirms olfactometer laboratory trials showing kairomonal activity of webbings produced by different species of pyralid Lepidoptera for *H. hebetor* (Strand et al. 1989). Moreover, foraging H. hebetor were shown to enter into bulk grain in previous studies (Schöller, 2000). In the present study, female *H. hebetor* were shown to exploit signals from moth webbings in bulk grain, too. Consequently, parasitisation of Indian meal moth larvae can be expected below the grain surface, too. This behaviour of *H. hebetor* can also be used to monitor the foraging behaviour of the wasps under practical conditions of storage. In wheat, more *H. hebetor* were traped compared to oats. This might be due to the three-dimensional structure of the bulk grain.

Both male and female *H. hebetor* were caught with the cone traps. The capture of females in unbaited traps indicates this trap type is able to record passivly the movement activity oft the parasitoids. Males could potentially be attracted by already caught females, however, in our trials, a signicantly higher number of females in the baited traps did not result in a significant increase in the number of males caught.

The results on monitoring showed the possibility to record data on the phenology oft he Indian meal moth and *H. hebetor* under practical field conditions. The abiotic conditions in differnt grain stores are subject to wide variation, consequently more field trials are needed in order to develop recommendations for biological control of the Indian meal moth.

Acknowledgement

This study was a joint project funded in the framework of Innovationsförderung im Pflanzenschutz (BLE) Förderkennzeichen 2814800611.

References

MOHANDASS, S., ARTHUR, F.H., ZHU, K.Y. AND J.E. THRONE, 2007: Biology and management of *Plodia interpunctella* (Lepidoptera: Pyralidae) in stored products. Journal of stored products research **43**, 302–311.

SCHÖLLER, M., 2000: Forager in the rye: Biological control of *Ephestia elutella* in bulk grain. In: Adler, C. & M. Schöller (eds.) Integrated protection in stored products. IOBC wprs Bulletin **23**(10), 149–159.

SCHÖLLER, M. UND S. PROZELL, 2001: Die Mehlmottenschlupfwespe *Habrobracon hebetor* (Hymenoptera: Braconidae) als Antagonist vorratsschädlicher Motten. Gesunde Pflanze **53**(3), 82–89.

STRAND, M.R., WILLIAMS, H.J., VINSON, S.B. AND A. MUDD, 1989: Kairomonal activity of 2-acylcyclohexane-1,3diones produced by *Ephestia kuehniella* Zeller in eliciting searching behaviour by the parasitoid *Bracon hebetor* (Say). Journal of chemical ecology **15**, 1491–1500.

A preliminary study of growth and development of *Cheyletus malaccensis* (Oudemans) under different humidity conditions

Lu Liu [1]*, Yang Cao [2], Peihuan He [2], Weiwei Sun [3], Qing Yu[2], Yi Wu [2]

[1] School of Food Science and Technology, Henan University of Technology, Zhengzhou 450001, China;

[2] Academy of State Grain Administration of China, Beijing 1000。37 China;

[3] Food Science College, Nanjing University of Finance and Economics, Nanjing 210023, China)

*corresponding author: L0315L@163.com

DOI 10.5073/jka.2018.463.117

Abstract

Cheyletus malaccensis (Oudemans) is a species of predatory mite, which is widely distributed in grain storage, and is a potential natural enemy of stored-product pests. Based on the typical temperatures and humidities that occur in granaries, the growth and development of *C. malaccensis* was studied at 24°C with different relative humidities (RH 65±2%, 75±2%, 85±2% and 95±2%). During this study, *C. malaccensis* was fed on *Acarus siro* (Linnaeus), a very important stored grain pest to investigate its potential to control this pest and production of this natural enemy in the laboratory. The results showed that *C. malaccensis* has five developmental stages, egg, larva, protonymph, deutonymph and adult. The deutonymph stage is absent in males. For females, the developmental time from egg to adult was shortest at 85±2 % RH and averaged 16.3 days; developmental time was longest at 65±2 % RH and averaged 18.6 days. The male mites in the 95±2% RH trials had the shortest developmental time which averaged 12.6 days; it was longest at 65±2% RH where it averaged 14.7 days. At 95±2

% RH, the male adult lived 83.5 d and its longevity from egg to adult was 95.8 d. Humidity had a significant effect on how long the adults lived and the duration of all developmental stages. At 85±2 % RH, the maximum average number of eggs per female, oviposition period and daily fecundity were 493.0, 46.2 d, and 10.3, respectively. This study provides basic biological parameters for *C. malaccensis*, a potential biological control agent for mite pests infesting stored grain.

Key words: *Cheyletus malaccensis*; development, reproduction, biological control

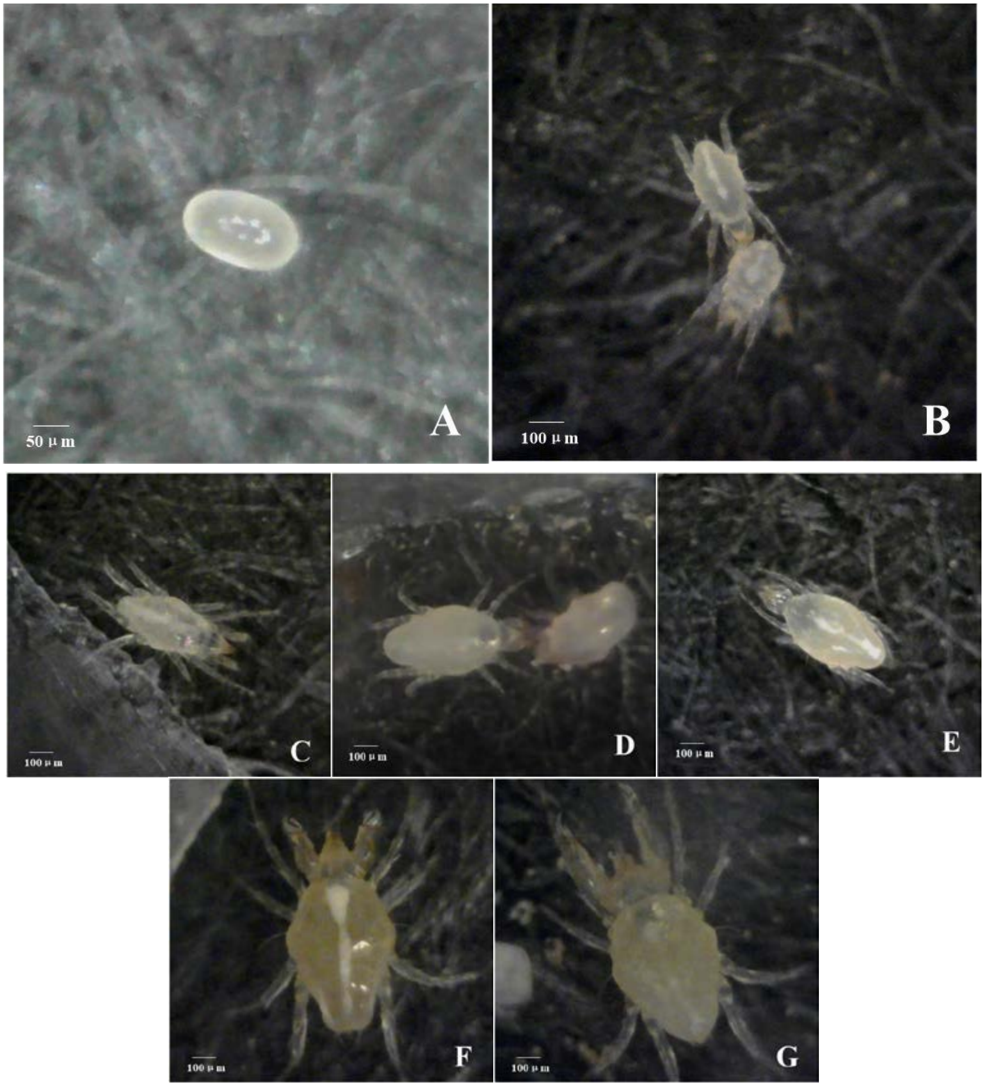

Fig.1 The development stages of *C. malaccensis* , A: Egg B: Larva C: Protonymph D: Deutonymph E: Hypopus F: Female G: Male

Table 1 The developmental duration of *C. malaccensis* **at different relative humidity conditions**

Relative humidity (%)	Egg(d)		Larva Mov. (d)		Larva Qui. (d)		Protonymph Mov. (d)		Protonymph Qui. (d)		Deutonymph Mov. (d)	Deutonymph Qui. (d)	Life history(d)		Adult(d)		Development duration of all stages	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Female	Female	Male	Female	Male	Female	Male
65±2	2.9±0.26	2.6±0.18	4.2±0.31	5.0±0.37	0.9±0.07	1.6±0.18	4.0±0.38	4.0±0.38	1.1±0.14	1.6±0.38	3.8±0.46	1.6±0.24	18.6±0.48	14.7±0.69	51.8±10.83	47.8±2.83*	70.2±10.79	61.8±2.98*

75±2	3.0±0.00	2.4±0.15	3.3±0.33	4.6±0.47	1.0±0.00	1.4±0.21	3.7±0.33	4.0±0.22	1.0±0.00	1.1±0.09	3.3±0.67	2.0±1.00	17.3±0.33	13.9±0.73	57.0±21.59	40.8±5.69*	74.3±21.26	54.7±5.50*
85±2	2.0±0.38	2.4±0.29	3.7±0.57	5.3±0.92	1.1±0.14	1.3±0.18	3.3±0.36	3.1±0.51	1.0±0.00	1.0±0.00	3.4±0.43	1.7±0.42	16.3±1.27	13.1±1.10	53.8±7.07	71.0±5.80*	70.0±6.72	83.5±6.00*
95±2	2.9±0.14	2.1±0.1	4.3±0.29	3.6±0.29	1.1±0.14	1.1±0.14	3.7±0.18	4.3±0.57	1.7±0.57	1.4±0.20	3.1±0.34	1.3±0.18	18.1±0.46	12.6±0.48	50.5±8.59	83.5±7.53*	68.7±8.39	95.8±7.61*

Note: The data in the table are means±SE. *Mean significantly different ($P < 0.05$).

Table 2 The developmental duration of stages and oviposition between *C. malaccensis* and *C. eruditus*

Prey	Predator	Temperature (℃)	Relative Humidity (%)	Sex		Egg	Larva		Protonymph		Deutonymph		Life history	No. of eggs per female	Oviposition period	Author
							Mov.	Qui.	Mov.	Qui.	Mov.	Qui.				
T. putrescentiae	*C. malaccensis*	24-25	75			4	3.5		3.5		5.5		19.5	73	6	Zhaopeng Shen
	C. malaccensis	25	80±5	Female		4.3	7.5		6.9		6.1		24.8			Palyvos 、Emmanouel
				Male	Virgin	3.9	7.4		6.7				18.0	47.6±6.9	15.3±0.6	
					Fertilized	4.3	7.8		7.2				19.3	88.6±10.1	17.5±0.5	
	C. eruditus	24	80			3.34	3.85	1.66	3.32	1.71	2.79	1.65	18.32			Bin Xia
L. destructor	*C. malaccensis*	18-22				5-6	3	2	3-4	2	3-4	3		77-107	14-16	Yanxuan Zhang
	C. eruditus	25	76			3.3	3.5		4.5		4.1			132.8	25.3	Barker
A. ovatus	*C.malaccensis*	25±0.1	75±2	Female		3.3	5.2	1.2	4.5	1.4	3.5	1.6	20-23		10.1±0.3	Saleh.M
				Male		3.3	5.2	1.3	4.4	1.6			15-17			
D. gallinae	*C. malaccensis*	25	80±5			4.74	5.24		4.38		3.96		18.38			Maicon Toldi 、Faleiro
A. siro	*C. eruditus*	24	75			5.0	7.8		7.2		6.3					Peihuan He

Table 3 The oviposition of ***C. malaccensis*** parthenogenetic at different relative humidity conditions

Relative humidity（%）	65±2	75±2	85±2	95±2
No. of eggs per female	418.0±91.90	427.3±178.44	493.0±104.52	348.2±101.06
Oviposition period	45.4±10.57	44.7±18.10	46.2±8.21	34.0±7.39
No. of eggs laid by each female per day	9.5±0.33	9.4±0.99	10.3±1.20	9.0±1.70
Max. no. of eggs laid by each female per day	23.6±1.81	19.3±1.86	20.0±1.00	21.2±3.30
Pre-oviposition	3.2±1.09	2.3±1.15	3.0±1.00	1.3±1.50
Post-oviposition	3.6±2.40	2.7±2.67	7.0±2.67	7.2±1.29

Note: The data in the table are means±SE.

References

WEI RIJI, ZHANG ZHENG, 2004. Biological control technology of "treating maggot with wolfberry" [C]. Guangxi Youth Academic Conference. 518-521.

XU XUENONG, LU JIALE, WANG ENDONG, et al, 2015. Predation breeding and application of predators[J]. Chinese Journal of Biological Control , 31(5): 647-656.

ZHANG YU, XIN TIANRONG, ZOU ZHIWEN, et al, 2011. An Overview of Researches on Grain Reserves in China[J]. Journal of Biological Hazards, (4): 139-144.

ŽĎÁRKOVÁ E, HORÁK E, 1990. Preventive biological control of stored food mites in empty stores using Cheyletus eruditus (Schrank)[J]. Crop Protection, 9(5): 378-382.

XIA BIN, GONG ZHENQI, ZOU ZHIWEN, et al, 2003. Predation efficacy of common meat crickets on predatory typha rot [J]. Journal of Nanchang University(Sciences Edition), 27(4): 334-337.

XIA BIN, LUO DONGMEI, ZOU ZHIWEN, et al, 2007. Predation function of common meat pupa on ellipse mealybugs [J]. ACTA ENTOMOLOGICA SINICA, 44(4): 549-552.

BUFFONI G, DI COLA G, BAUMGARTNER J, et al, 1997. The local dynamics of acarine predator-prey (Cheyletus eruditus - Dermanyssus gallinae) populations: identification of a lumped parameter model[J]. Mitteilungen der Schweizerisches Entomologisches Gesellschaf, 70(3-4): 345-359. Toldi M, Faleiro D C C, Silva G L D, et al, 2017. Life cycle of the predatory mite Cheyletus malaccensis (Acari: Cheyletidae) fed on poultry red mite Dermanyssus gallinae (Acari: Dermanyssidae)[J]. Systematic & Applied Acarology, 22(9): 1422.

HE PEIHUAN, ZHANG TAO, WU WEI, et a, 2016l. Study on the predation ability of common meat lice on nine kinds of stored grain pests[J]. China Grain and Oil Magazine, 31(11): 112-117.

GONG ZHENQI, XIA BIN, TU DAN, et al, 2003. Advances in Research on Ecology of Meat Carp[J]. Journal of Biological Disasters, 26(4): 152-155.

BARKER P S, 1991. Bionomics of Cheyletus eruditus (Schrank) (Acarina: Cheyletidae), a predator of Lepidoglyphus destructor (Schrank) (Acarina: Glycyphagidae), at three constant temperatures[J]. Canadian Journal of Zoology, 69(9): 2321-2325.

HE PEIHUAN, WU YE, ZHENG DAN, et al, 2017. Study on the Growth and Development of Common Meat Pupa with Different Grain Temperature and Humidity[J]. Cereals, Oils Food Science and Technology , 25(2): 89-94.

CHEN QIZONG, 1994. Investigation and Study on the Pests of Stored Products in China: A Discussion on the Historical Insect Pests of the National Food System[J]. Cereals Science and Technology, (5): 6-9.

LI XIAODA, LI GUOCHANG, HAO LINGJUN, 1988. Investigation and Research on Stored Mites in Henan Province[J]. Journal of Henan University of Technology(Natural Science Edition), (4): 67-72.

TIAN JIANGUO, REN ZHENGDONG, ZHANG TAO, 1988. Preliminary Report on the Composition and Occurrence Situation of Grain Anchovy in Shaanxi Province[J]. Grain Processing, (4): 3-6.

CHEN QIZONG, 1990. Preliminary Report on the Investigation of the Fauna (Insect and Mites) in the Tibet Autonomous Region[J]. Journal of Henan University of Technology(Natural Science Edition), (3): 29-41.

WU GUOXIONG, ZHENG WEI, LAN BO, et al, 1990. Survey of stored mussels in Jiangxi Province [J]. Grain Storage, (4): 15-22.

PALYVOS N E, EMMANOUEL N G, 2009. Temperature-dependent development of the predatory mite Cheyletus malaccensis (Acari: Cheyletidae)[J]. Experimental & Applied Acarology, 47(2): 147-158.

SHEN ZHAOPENG, 1975. Life history of the first Chinese meat carp and the meat carp of Cheyletus malaccensis in China[J]. ACTA ENTOMOLOGICA SINICA , 18(3): 316-324.

HE PEIHUAN, CAO YANG, WU YI, et al. A device for observation and storage of aphids and insects: China, 201520476487.0[P]. 2015-09-20.

KUCEROVA Z, HROMADKOVA J, 2009. Egg Morphology of the Predatory mite, Cheyletus malaccensis (Acarina: Cheyletidae)[J]. Entomologia Generalis, 32(1):35-40.

NAKATANI YOSHIYUKI, 1975. Cheyletus malaccensis Oudemans, Patterns of each stage of 1903 [J]. Hygienic animals, 26:151-165.

ZHANG YANMIAO, HOU AIPING. Study on the Relationship between Meat Carp and Malaria in Malacca[J]. Fujian Journal of Agricultural Sciences, (1): 44-47.

SALEH S M, ELHELALY M S, ELGAYAR F H, 1986.. Life history of the predatory mite Cheyletus malaccensis (Oudemans)[J]. Acarologia,

PALYVOS N E, EMMANOUEL N G, 2011,. Reproduction, survival, and life table parameters of the predatory mite Cheyletus malaccensis (Acari: Cheyletidae) at various constant temperatures[J]. Experimental & Applied Acarology, 54(2): 139-150.

PULPAN J, VERNER P H, 1965. Control of Tyroglyphoid Mites in Stored Grain by the Predatory Mite Cheyletus eruditus (Schrank)[J]. Canadian Journal of Zoology-revue Canadienne De Zoologie, 43(3): 417-432.

Evaluation of the potential value of the F_1H and F_2H Diatomaceous earth formulations as grain protectants against *Rhyzopertha dominica* (Fabricius) (Coleoptera: Bostrichidae)

Anita Liška[1*], Zlatko Korunić[2], Vlatka Rozman[1], Pavo Lucić[1], Renata Baličević[1] Josip Halamić[3], Ines Galović[3]

[1]University of Josip Juraj Strossmayer in Osijek, Faculty of Agriculture in Osijek, Vladimira Preloga 1, 31000 Osijek, Croatia
[2]Diatom Research and Consulting Inc., 14 Tidefall Dr. Toronto, ON, M1W 1J2, Canada
[3]Croatian Geological Survey, Sachsova 2, 10000 Zagreb, Croatia
Corresponding author Email: aliska@pfos.hr
DOI 10.5073/jka.2018.463.118

Abstract

An insecticidal efficacy of two **newly developed** grain protectant formulations were assessed against lesser grain borer *Rhyzopertha dominica* (Fabricius) (Coleoptera: Bostrichidae) on wheat and corn after 6 months period of. Tested formulations, marked as F_1H and F_2H, based on inert dust, laurel leaves, lavender essential oil, corn oil, silica gel (both F_1H and F_2H) and pyrethrin (only F_2H) were tested at six doses (from 100 ppm to 600 ppm) depending on formulation and type of grain. The appropriate weights of each formulation, were added seperately to plastic containers containing 10 kg of wheat or corn. An initial population of 200 adults of *R. dominica* were added into each container and left under natural environmental conditions for up to 6 months. A commercial diatomaceous earth (DE) insecticide, Celatom® Mn 51, was used for the comparison of the results, in addition to the untreated control. After six months, both formulations showed higher insecticidal effect than DE Mn 51 in corn and in wheat. Furthermore, the initial population of *R. dominica,* introduced in wheat was suppressed almost completely, with only 0.7%-5.3% live adults found, depending on formulations and dose. The order of efficacy was F_1H>F_2H>DE Mn 51. Similar suppression of the initial population was recorded in corn, where F_2H was slightly more effective than F_1H with 2.0%-10.6% and 4.1%-9.5% live adults found, respectively. At the same time, in the treatments with DE Mn 51 there were 4.7%-74.7% and 33.4%-56.1% live adults in wheat and corn, respectively.

Keywords: inert dust, botanicals, grain protectant, stored product insects, insecticidal effect