The Libyan Journal of Science (An International Journal): Volume 19A, 2016

Effects of Egg Parasitoid *Chelonus phthorimaea* Gahanon Potato Tuber Moth *Phthorimaea operculella* Zeller

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Abstract

This study revealed the significance of laboratory rearing of potato tuber moth (PTM) *Phthorimaea operculella* egg parasitoid *Chelonus phthorimaea*. The initial rearing counts of 50 parasitoid pupae imported from Tunisia were exposed to 270 potato tuber moth *P. operculella* eggs. During the period of this research the outcome of 9106 PTM parasitoids resulted in 15394 PTM parasitized eggs out of 34705 reared in 47 cages with an infestation rate of 21-25%. The parasitoid showed an infestation rate of 17 PTM eggs/female, with an increase of 22% in pupal parasitism. These findings were in accordance with previous reported studies. Because of high parasitoid population production, rearing of PTM was limited to 50%. The power of the ordinary least squares (OLS) model was determined for the rate of parasitoid and the coefficient of determination R^2 = 71.31 %. The results clearly indicated the powerful effect of the oophagous, *C. phthorimaea* of potato tuber moth, *P. operculella* under laboratory conditions.

Keywords: Potato tuber moth (PTM), *P. operculella*, egg parasitoid, *C. phthorimaea*

Accepted for publication: 16/8/2016

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المستخلص

توضح هذه الدراسة أهمية التربية المعملية للطفيل القاتل *C. phthorimaea* لبيض فراشة درنات البطاطس *Phthorimaea operculella* كعامل كبير للحد من هذه الآفة في برنامج المكافحة الحيوية. لقد تم استجلاب عدد 50 عذراء للطفيل القاتل للبيض من تونس، واستخدمت معملياً وتم تعريض نحو 270 لبيض فراشة البطاطس. تقدر بين 21– 25%. أظهر الطفيل القاتل لبيض فراشة درنات البطاطس نسبة إصابة 17 بيضة لكل أنثى، وبنسبة زيادة لإصابة عذارى فراشة درنات البطاطس بنحو 22%. إن النتائج المتحصل عليها في هذا البحث خلال البرنامج البحثي لهذه الدراسة كان ناتج 9106 للطفيل القاتل إصابة نحو 15394 بيضة لفراشة درنات البطاطس كاملة التطفل من مجموع تربية 34705 فراشة داخل 47 قفص تربية، وبتسجيل نسبة إصابة تتوافق مع معظم الدراسات والبحوث السابقة الموثقة في هذا المجال. ونظراً للكثافة العالية الناتجة عن عملية التربية المعملية للطفيل القاتل تم خفض تربية الطفيل القاتل إلى 50% لغرض استمرارية العمل. كما أُستخدم نمط معامل القوة الإحصائي (OLS) لتحديد الأثر الفعلي للتطفل على بيض فراشة درنات البطاطس، وكان معامل التحديد للمعادلة R^2 = 71.31 الذي يؤكد على إيجابية التطفل العالية على بيض هذه الآفة الاقتصادية معملياً. بالإضافة إلى الأثر الفعال في إدخال هذه التقنية في مجال المكافحة الحيوية ضمن إطار المكافحة المتكاملة لفراشة درنات البطاطس في ليبيا.

Introduction

The potato tuber moth (PTM) *Phthorimaea operculella* (Zeller), Lepidoptera: Gelichiidae), is the most damaging pest of potatoes, *Solanum tuberosum* L., Solanacae, in warm temperate and subtropical climates[6]. During the growing season, the potato tuber moth mines into foliage and stems, while at plant senescence adults lay eggs in exposed tubers in the soil. At harvest, tubers do not always show signs of damage but may harbor eggs and early instar larvae. This may result in severe losses in the absence of adequate control measures [3].

The PTM is the single most significant insect pest of potatoes in the field and storage in North Africa and Middle East [8]. In Libya as most of other countries, farmers routinely apply chemical insecticides to protect their crops. This reliance on chemical insecticides not only increases cost but also has serious deleterious effects on human health, environment and development of insect resistance to insecticides.

The Libyan annual potato production is more than 100.000 tons. Potatoes are grown in two seasons, spring and fall, mainly on coastal areas of Libya. Potatoes varieties for Libyan market are mainly imported from Europe and Canada. The domestic availability of potatoes in Libya averages 129.000 tons, 83% is used for human consumption, 12% as seed, and 5% wasted [5, 7].

Faced with serious pesticide problem, scientists started to seek safer alternatives such as the use of parasitoids, the agents of biological control, to replace toxic chemicals in their integrated pest management (IPM) strategies and tactics. Parasitoids are species whose immature stage develops on or within a single insect host, ultimately killing the host. According to literature, the larval parasitoids of potato tuber moth are mainly, *Diadegma molliplum, Orgillus lepidus* and *Apenteleslitae nixonvar operculella* [15,17]. *Trichogramma* species, egg parasitoids, are among the most reared and used natural enemies in the world [12, 17]. Worldwide, 28 *Trichogramma* species are released in 28 crops including potato for biological control of *P. operculella* [11].

Copidosoma koehlri, a small encysted egg-larval parasitoid of the potato tuber moth, is one of several exotic natural enemies released in Australia in 1940 and 1960's [13]. Of the three parasitoid species established in Australia, *C. koehleri* is an egg parasitoid specific to *P. operculella* [2], appears most suited to mass rearing for innudative biological control of PTM [13]. In California the PTM, supports a parasitoid complex that consists of at least 12 species [10,16]. Of these, *C.phthorimaea* Gahan, (Hymenoptera: Braconidae) is the only egg-larval parasitoid. Little has been published on *C. phthorimaea* subsequent to the original description by [9] and the brief report by [10] who listed it as *C. sbosboneanorum* Vierek. The parasiroid *C. blackburni*, egg parasitoid, has proved its worth as a component in the integrated pest management of PTM [4, 1].

Materials and Methods

The potato tuber moth (*P. operculella*) used in this experiment came from rearing room for production of the potato tuber moth located at the Agriculture Research Center, Tripoli, Libya. The egg parasitoid**,** *C. phthorimaea* pupae were imported from the culture maintained at the Institut National de Recherche Agronomique de Tunis (INRA).

The insect rearing room equipped with: lightning photoperiod program of 12 h L: 12 h D throughout the study; a constant temperature of 25 ± 2 °C with 70 ± 5 % relative humidity (RH).

Laboratory Rearing of the Potato Tuber Moth and Egg Parasitoid

Pupae from stock culture were collected, screened and counted. Approximately 350 to 400 pupae/cage were transferred into sterilized cages. The newly emerged adults (5 to 7 days) in each cage, were fed 10 % sugar solution on soaked wicks. After mating and oviposition white eggs glued on bands of black cardboard added inside each cage were collected daily.

A batch of (3 to 5 kg) of cleaned and sterilized potatoes were punctured on the surface with a pin brush to facilitate larval first instars entrance within tubers. Tubers infested with white eggs are glued on black cardboard bands. Eggs hatch within 7 to 9 days and newly larvae find their way into tuber through entrance holes.

After larval metamorphosis and development inside tubers within a period of 9 days, infested potatoes were placed in rearing trays containing sterilized sand layer. Larval fourth instars (16 to 24 days) migrate downwards to pupate in the sand. Pupae were collected, sieved and removed into sterile rearing cages for rearing the next generation.

Rearing of egg parasitoid, *C. phthorimaea*, took place in the same rearing chamber at similar climatic conditions and needs. For production of the egg parasitoid, 50 pupae of *C. phthorimaea* were transferred into special rearing vials with source of 10 % sugary feeding solution. After a period of 5 to 7 days new wasps emerged. A quantity of 270 undamaged potato tuber moth eggs were exposed to *C. phthorimaea* to be parasitized within 48h. Eggs on paper cards are then put on sterilized punctured tubers on sandy trays for the insect and/or the parasitoid development in a time period of 7 to 9 days. Pupae were collected and evaluated for parasitism. Parasitized potato tuber moth pupae were placed into rearing vials and emerging wasps fed and exposed to host eggs for new trials.

Results

Table.1 shows the total number of rearing egg parasitoid, *C. phthorimaea* on its host eggs PTM and percentage of parasitism for 11 weeks. The initial counts of the pupal parasitoid were 50 pupae with an 270 PTM eggs. During the first date of mass rearing and parasitism a total of 119 PTM pupae were parasitized.

By end of the experiment period (Table1) the data demonstrated that 9106 pupae of *C. phthorimaea* being able to parasitize a total of 15394 PTM eggs out of 34705 introduced normal PTM eggs. In comparison, 4939 normal PTM eggs were produced.

The total pupae of both potato tuber moth and *C. phthorimaea* were 20333 pupae with a loss of 12.5 % of initial egg count.

Due to high effect of *C. phthorimaea* parasitism on PTM egg counts, rearing rates of the parasitoid were reduced to 21 % during weeks 9 – 11 in order to maintain the stock culture of the potato tuber moth for further studies.

Figure 1 reveals the association between the parasitized PTM pupae and the rate of *C. phthorimaea* parasitism. Ordinary Least Square (OLS) and exponential model were used:

$$Y = ae^{*-bx}$$

Where (a, b) as parameters, Y no. of PTM pupae and X as the rate of parasitism. Therefore, Y = 2059.437 * exp (- 0.098 * A1/B1). A1/B1 = rate of parasitism.

Table 1. The total numbers of mass rearing egg parasitoid, *C. phthorimaea* on its host PTM, *P. operculella* and percentage of parasitism.

Week	Initial No. Pupae Parasitoid	No. Eggs PTM	Total No. Pupae PTM	Total No. Parasitoid Produced	No. Pupae Produced PTM
1	50	270	157	119	38
2	119	560	323	256	67
3	256	1420	799	626	173
4	626	2205	1329	1032	297
5	1032	3623	2177	1636	541
6	1636	4927	2906	2156	750
7	2156	6180	3560	2666	894
8	2666	13281	7782	5877	1905
9	300	1277	764	595	169
10	150	600	334	266	68
11	115	362	202	165	37
Total	9106	34705	20333	15394	4939

The power of the (OLS) model was determined and the rate of *C. phthorimaea* parasitism, the coefficient of determination, was found to be R^2 = 71.31. The results clearly indicate the powerful effect of the oophagous, *C. phthorimaea* on PTM eggs under laboratory conditions.

Discussion

Integrated pest management (IPM) involves using several strategies to control pests by using more than one method together such as biological control with chemical control. IPM aims to keep or maintain pest population at lowest level. It relies as much as possible on natural factors to restrict the buildup of pests. Biological control includes parasitoids, predators and pathogens.

Parasitoids are species whose immature stage develops on or within a single insect host, ultimately killing the host. Hence, the value of parasitoids as natural enemies. The most important parasitoid orders are Hymenoptera and Diptera. There are many species of parasitoids such as: 1. egg parasitoids: *Trichgramma sp*. 2. larval parasitoids: *Apanteles sp.*, *Bracon sp*., *Diadegma sp*. and *Origilus sp*. 3. egg larval parasitoids: *Chelonus sp*. such as, *C. caucasicus*, *C. curvimavulatus*,

C. kellieae, C. phthrimaea, C. blackburni, C. subcontractus, and *Copidosoma sp*. such as *C. desantsi* and *C. koehleri*.

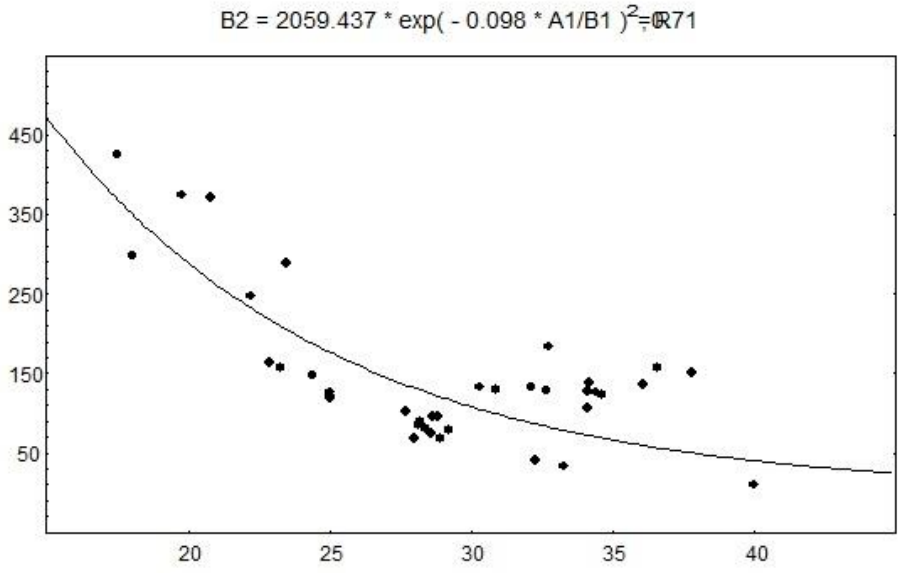

Fig. 1. Model of relationship between pupal counts and rate of *C. phthorimaea* parasitism.

The parasitoid *C. phthorimaea* has proved its worth as a component in the integrated pest management of *P. operculella* [4]. Laboratory studies have shown that *P. operculella* is the most suitable laboratory host for rearing *C. phthorimaea* due to its short developmental time when reared on this host and also because of fairly good percent parasitism, longevity, and fecundity observed [1]. In California the PTM supports a parasitoid complex that consists of at least 12 species [10, 17]. Of these *C. phthorimaea* is the only egg parasitoid.

The morphology of *C. phthorimaea* males and females in general are black with brown-yellow basitarsus, tibia and femur. Wings are hyaline. Both males and females are approximately 3 mm long. The female's antenna is 14 segmented and average of 1.64 mm in length. Those of the male are 16 segmented and average 2.64 mm long. These morphological measures are in agreement to those of Gahan [9].

The *C. phthorimaea* egg is hymenopteri in form is translucent, cylindrical and round at both ends. The surface is smooth, not sculptured, and the cephalic region is larger than the caudal region at oviposition. Laboratory observations revealed

that the female of the *C. phthorimaea* positions herself with her abdomen above the PTM host egg and lowered prothoracic legs. The ovipositor was extended and penetrated the host egg. After completion of oviposition, the ovipositor was withdrawn and the abdomen straightened. The female then resumes her search for more host eggs. This behavior is similar to other species of *Chelonus* observed by other workers in this field.

Pupa stage of *C. phthorimaea*, is exarate. Early pupal stage is pale yellow, gradually darkening as development progresses. The pupa lies motionless within the cocoon, which is parchment in appearance. The cocoon, cylindrical to ovoid, is constructed of glistening white threads. The meconium is located at the caudal extremity of the cocoon. Pupation occurs 16 days after oviposition.

The population development of the PTM parasitoid *C. phthorimaea* is different from field and laboratory conditions. For example, in spring in the beginning of vegetation period, a typical situation in parasitoid-host-interaction is visible in the field. The population development of the potato tuber moth precedes the parasitoids. After planting the potatoes, the parasitizaion starts with the first symptoms of moth infestation on the leaves. The parasitization rate starts very low and increases with increasing infestation. The parasitization is independent of the potato growth stage but depends on planting dates. In the potato growing season the parasitization is much higher (78-86%) in the fall season in comparison to spring (18-35%) as reported by Kroschel & Koch [14]. This could be due to influence of duration of the PTM life cycle and temperature.

This study illustrates the significance of laboratory rearing of PTM egg parasitoid *C. phthorimaea*. The initial rearing counts of 50 parasitoids pupae were exposed to 270 potato tuber moth eggs. During the period of this research the outcome of 9106, *C. phthorimaea* parasitoids resulted in 15394 PTM parasitized eggs out of 34705 reared in 47 cages with an infestation rate of 21-25%. The parasitoid, *C. pthorimaea*, showed an infestation rate of 17 PTM eggs/ female parasitoid with an 22% increase in pupal parasitism. These findings were in accordance with published studies. Because of the high parasitoid population production, mass rearing of *C. phthorimaea* was limited to 50% (Table.1).

The evaluation of the *C. phthorimaea* mean parasitism was carried out according to the Ordinary Least Square Model (LSM) and the exponential model = ae*- bx, where (a,b) as parameters and Y (no. PTM pupae) and X (rate of parasitism). Therefore, Y=2059.437* exp (-0.098* A1/B1). A1/B1 = rate of parasitism.) (Fig.1).

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