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Biological characteristics of the codling moth, *Cydia pomonella* (L.), wild population from Southern Syria

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ABSTRACT. Sex ratio, weight, fecundity, fertility and longevity of codling moth, *Cydia pomonella* (L.) wild adults from wild populations of Southern part of Syria were examined. In addition, percentage of larvae entering diapause from each generation was investigated and the relationship between female weight and fecundity was examined. The results showed that sex ratio was about 1: 1 (males to females), adult weight ranged, on average, from 14.4 to 25.7 mg for spring generation males and females respectively and from 19.5 to 32.6 mg for summer generation males and females in the same order. Fecundity of the spring generation moths was close to 85 eggs/female; this number increased by about 30% for summer generation females and a strong relationship was found between female weight and fecundity. Adult fertility, for both generations (spring and summer), exceeded 90%, longevity ranged from about 10 days for spring generation adults to about 9 days for summer generation moths and males lived little longer than females. These results may serve as a reference in quality control measures for codling moth mass rearing in Syria.

KEY WORDS: Codling moth, *Cydia pomonella,* population characteristics, Syria.

INTRODUCTION

Syria has a large apple production, due to suitable climatic conditions. The total apple acreage according to 2004 statistics is about 50.000 ha (ANONYMOUS 2004). The codling moth, *Cydia pomonella* (L.), is a very important pest of apple in most parts of the world (CHAPMAN 1973, BARNES 1991) and a key pest of apple in Syria (TALHOUK 1954). The insect is also a serious pest on pear, quince and walnuts, and causes tens of millions of dollars in losses to the fruit industry every year. Without effective control measures, the pest could

destroy 100% of the apple crop, and even with control the losses could reach 10% (SCHWARTZ & KLASSEN 1981). In Syria, the pest has two generations (spring and summer generations) per year and infestation rate in neglected apple orchards is 80-100% (SCHNEIDER 1957, MANSOUR 2002).

Chemical control of this pest has many drawbacks including insecticide resistance (VARELA et al. 1993, KNIGHT et al. 1994), reduction in numbers of natural enemies (ROTHSCHILD 1982) and the creation of secondary phytophagous mite problems (Carde & Minks 1995). In addition, high insecticide residues on fruit due to the intensive insecticide spray programs used for codling moth control in Syria have caused difficulties in exporting the country's surplus of apples (Al-Motny 1997).

An alternative approach to codling moth control is the use of the sterile insect technique (SIT). This method depends on releasing sterile males into the natural population to mate with wild females and thus making them unable to reproduce. One of the most important prerequisites for the success of this method is the ability to mass rear the insect involved in large numbers without adversely affecting its competitive ability (KNIPLING 1964). Techniques for codling moth mass rearing are available (BRINTON et al. 1969, TOBA & HOWELL 1991, HOWELL 1967, HATHAWAY et al. 1971) and a rearing diet with local ingredients has been developed in Syria (MOHAMAD et al. 1997). To ensure the quality of the produced insects, however, certain important biological characteristics of the mass reared moths should routinely be monitored (MOORE et al. 1985). The results of the examined parameters are usually compared with that of natural insects. This makes it necessary to study these characteristics in natural insects or insects reared on their natural host.

In this article, data on sex ratio, weight, fecundity, fertility and longevity of adults from a wild codling moth population in the southem part of Syria were collected. In addition, the relationship between female weight and fecundity was examined and percentage diapause in larvae from the two larval broods was investigated.

MATERIALS AND METHODS

Sex ratio, weight, fecundity, fertility and longevity

Overwintering codling moth larvae were collected from several locations in the southem part of Syria (Sweida) during the month of March, and larvae resulting from the spring generation were collected in July of the same year (2005). Larvae were collected in cardboard traps, 10 cm wide, placed around tree trunks in neglected or heavily infested apple orchards. The traps were set in June to collect spring generation larvae and in August and September to collect overwintering larvae. Collected larvae were brought to the laboratory, incubated at 26 ± 2^{O}C, 16:8 DL cycle and kept under daily observation. Emerging moths were sexed, the number of insects from each sex was recorded and sex ratio (male:

female) was calculated. Moths were weighed using an electrical balance with a precision of 0. 1 mg and the average weight/moth (male or female) was calculated.

Pairs of moths (one male and one female) were formed from emerging adults, placed in a covered clear plastic cylindrical container (3.5 X 5.5 cm) lined with wax paper for egg laying, female weight was recorded and the container was labeled appropriately. The moths were provided with water on cotton wads, checked daily, dead ones were counted, their sex and number was recorded and average moth longevity was calculated. Six days later, eggs were collected, incubated at 27 ± 1^{O}C for one week and examined under a binocular microscope for egg hatch. The number of hatched eggs was recorded and percentage egg hatch (fertility) was calculated by dividing the number of hatched eggs by the number of laid ones. Female fecundity was calculated by dividing the total number of produced eggs by the number of females.

Effect of adult weight on female fecundity

To examine the relationship between adult weight and female fecundity, the number of eggs deposited by each female was plotted against its weight and the relationship was examined using regression analysis.

Percentage diapause

Larval diapause in codling moth field population from the spring and summer generations in the southern part of Syria was examined using mature larvae caught in corrugated cardboard traps. Cardboard traps were placed around tree trunks in neglected or heavily infested apple orchards in June and examined on a biweekly basis starting early July. Collected larvae were brought to the laboratory where they were placed individually in clear cylindrical plastic containers (3.5 X 5.5 cm) provided with cardboard strips to serve as a pupation site and incubated at 26 ± 2^{O}C and 50 ± 10% RH. The larvae were examined weekly for over two months and the number of pupating and diapausing larvae was recorded. Percentage diapause was calculated by dividing the number of diapausing larvae on the total number of examined insects.

RESULTS

Tables 1 and 2 show the results of examining sex ratio, weight, fecundity, fertility and longevity of codling moth adults from spring and summer generations. The data indicate that sex ratio was in favour of females but, the difference was not significant. The average moth weight for males and females respectively ranged from 14.4-25.7 mg for spring generation insects to 19.5-32.6 mg for summer generation moths. On average, fecundity was about 84.7 eggs/female for spring generation and 112.1 eggs/female for the summer generation moths. The results also showed that summer generation males and females lived, under

lab conditions, about 9.3 and 8.7 days respectively while spring generation adults lived a little longer and, in both cases, males lived little longer than females.

Table 1. Sex ratio, weight, fecundity, fertility and longevity of codling moth wild adults from the spring generation.*

Sex	**Examined character**				
	Sex ratio (%)	Weight (mg)	Fecundity (eggs/female)	Fertility (%)	Longevity (%)
Males	49.5	14.4 ± 2.7	X	93.5 ± 7.4	10.4 ± 2.5
Females	50.5	25.7 ± 4.5	84.7 ± 34.7		9.6 ± 2.7

*Sex ratio and weight are based on examining 600 insects. Fecundity, fertility and longevity are based on 200 pairs.

Table 2. Sex ratio, weight, fecundity, fertility and longevity of codling moth adults from the summer generation.*

Sex	**Examined character**				
	Sex ratio (%)	Weight (mg)	Fecundity (eggs/female)	Fertility (%)	Longevity (%)
Males	49.0	19.5 ± 3.9	X	92.9 ± 9.3	9.3 ± 2.6
Females	51.0	32.6 ± 4.8	112.1 ± 33.4		8.7 ± 2.2

*Sex ratio and weight are based on examining 600 insects. Fecundity, fertility and longevity are based on 200 pairs.

Fig. 1 shows the relationship between female weight and fecundity. The figure indicates a very good relationship between female weight (x) and fecundity (y). The strength of this relationship is confirmed by a large correlation coefficient ($R2 = 0.72$, $P < 0.001$). The regression equation ($y = 6.44x-80.74$) predicts that, on average, wild moths from spring generation lay 80.4 eggs/female. This prediction goes very well with the experimental data collected from field moths (average eggs/female is 84.7).

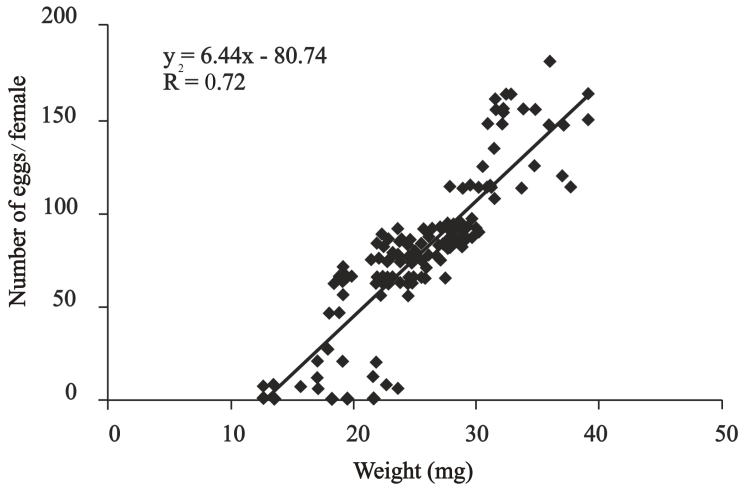

Fig. 1. The relationship between female weight and fecundity in codling moth adults (spring generation) collected from the southern part of Syria.

Fig. 2 shows the incidence of diapause in codling moth larvae collected from the southem part of Syria. The figure shows that a small percentage < 5%) of spring generation larvae entered diapause. The ratio of diapausing larvae, however, increased with time, which corresponds to decrease in the daily photoperiod, and reached 98% for larvae collected after the middle of September.

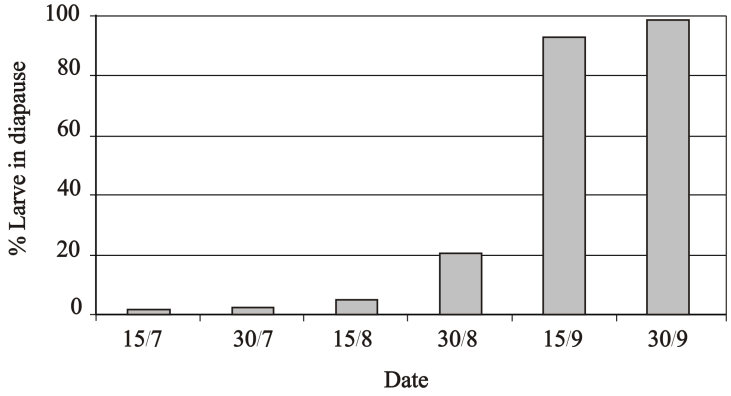

Fig. 2. Diapause incidence in codling moth larval populations from different larval broods collected from the southern part of Syria.

DISCUSSION

The codling moth is a key pest of pome fruits in Syria and causes tens of millions of dollars in losses to the fruit industry every year. The heavy losses to apple production caused by codling moth infestation, and difficulties in exporting fresh fruits due to high insecticide residues, has led to consideration of a new strategy for controlling this pest. The new policy aims to reduce farmer's reliance on pesticides and the SIT is seriously considered to control and/or eradicate this pest from the southern part of the country.

KNIPLING (1964) enumerated nine basic requirements for the success of SIT, and BUTT (1973) listed the requirements to implement this method for codling moth control or eradication. One of the most important requirements for the success of this technique is the ability to rear this insect in large numbers and with acceptable quality. Interbreeding and adaptation to lab conditions may affect quality of the data from mass reared insects. Therefore, important viability characteristics of the reared moths should be routinely be monitored and the results are compared with data collected from natural insects or insects reared, on their natural host (MOORE et al. 1985). Consequently, establishing reference values for such characteristics is very important.

Determining sex ratio of the wild population for a particular insect is very important in a sterile insect release program. This is because the size of the next generation is very much influenced by this ratio. Trapping adults for sex ratio determination is usually very convenient and can be useful. It is sometimes, however, misleading especially when it is done for only a short period of time. This is because one sex may emerge before the other or lives longer (DE JONG et al. 1971, GLASGOW & PHILIPS 1971). The safest procedure for establishing sex ratio is by sexing the emerged individuals for reared insects. Our results using the method of rearing insects showed that codling moth wild population has a sex ratio of approximately 1: 1 (males to females) with the percentage of females being a little higher than males. These results agree with those reported before by NOWCOMMER and WHITCOMB (1924), TADIE (1957), and MACLELLAN (1976) which indicate that codling moth is disposed to produce more females than males.

The results of this work also show that females are heavier than males and that summer moths (males and females) are heavier than spring generation moths which agrees with data reported by several authors before (GEIER 1963, HOWELL 1970, DESEO 1971, HATHAWAY et al. 1971). The reduced moths weight of spring generation could be due to overwintering larvae developing under short day conditions. The evolutionary advantage of this could be to guard against over utilisation of limited food supply by first generation larvae (DESEO 1973, DESEO & SARINGER 1975, RIEDL 1983).

Fecundity, which is an important biological characteristic to consider in mass rearing seems to be related to weight; the heavier the females, the more fecund they are. This explains the increased fecundity of summer females as they were heavier. High fecundity of lab reared females which ranged, on average, from 136 to 230 eggs/female (DESEO 1971, GEIER & BRIESE 1978, HOWELL 1981, BATHON et al. 1991, BLOEM et al. 1997), may be related to their higher weight as they are fed on a very nutritious diet. Our data agree with

those reported before by GEIER (1963) for insects natural populations and emphasise the importance of producing females of an acceptable weight in a codling moth mass rearing facilities.

Longevity is an important factor in male competition; the more they live, the more their chance of mating. The results of this study showed that wild moth lived, on average, about ten days under lab condition. This is similar to data reported by HOWELL (1981) and the reduced longevity of summer generation moths may be caused by higher temperature (HAGLEY 1972).

It has long been known that some codling moth larvae go to diapause in the middle of the summer and that the proportion of larvae that enter this condition increases towards the fall (HAMMER 1910). DICKSON (1949) demonstrated that it was a photoperiodic reaction to the decreasing day length, which caused larvae to enter diapause. In this study, a notable portion of the individuals of the spring generation larvae did not develop to adults. Instead, they went to diapause inside their cocoons and postponed activity. As weather conditions and day length during June and July are suitable for larval development in Syria, the incidence of diapause in some individuals of the spring generation larvae indicates an influence of some other factors on diapause induction. Genetics have been reported to play a role (WILDBOLZ & RIGGENBACH 1969) and this mechanism for diapause induction could serve as a protection mechanism for codling moth Population in years of no or very low fruit set (SHEL'DESHOVA 1967). The disadvantage of this phenomena for a sterile insect release program, however, is that it complicates the process of estimating the targeted insect population, a necessary step for estimating the required number of moths to release.

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