ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Study of the dynamics of codling moth larvae (*Cydia pomonella* L.) in three varieties of Apple (*Malus domestica* Borkh.) in the region of Laanoucer (Morocco).

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ABSTRACT

Codling moth (*Cydia pomonella* L.) is an important pest of Apple worldwide. Chemical control is mostly used to eradicate the insect. However, the high frequencies of treatment have harmful effects on human health and the environment. Codling moth damages crops exclusively on larval stage. Therefore, a possible development of alternative method of codling moth larvae control ought to be based on the study of larvae dynamics. The observation of codling moth Larvae dynamics considering canopy aspect (north, east, south, and west) and canopy height (bottom, middle, and top) of apple trees in the region of Laanoucer (Morocco), confirms that the Golden Delicious variety is more sensitive to the damage caused by the first generation larvae compared to the Royal Gala and Starking Delicious varieties. Second generation larvae cause more damage in the Royal Gala and Golden Delicious varieties. Also, canopy aspect of apple trees have influenced attacks caused by the first and second generations of codling moth larvae in the three studied apple varieties. Canopy height has influenced the infestation by larvae of the first generation in Royal Gala and the infestation by larvae of the first generation in Golden Delicious.

Keywords: *Cydia pomonella*, larvae dynamic, larval infestation, *Malus domestica*

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ISSN: 0975-8585

INTRODUCTION

The codling moth is a serious insect pest of apple. It causes enormous damage on different varieties of Apple. This is the most important insect pest of Apple globally [1, 2] and inflicts an infestation rate estimated at 80% in the orchards of Apple [3].

The codling moth *Cydia pomonella* L. causes damage only during its larval stage [4, 5]. Neonate larvae are able to move through apple trees and dig deep tunnels in the fruit which drops eventually [6]. Postharvest damaged fruits are consequently withdrawn from the market [7].

To deal with this problem, chemical control is mostly used [8, 9] They are preferred because they are often the cheapest and most efficient strategies available [10]. However, Chemical pesticides have direct and indirect risks on health and environment [11]. Therefore, any alternative control method development should be based on the study of codling moth host choice. This will be of great importance in the development of strategies disrupting the trophic and reproductive behavior of the insect and the crop protection [12].

The distribution of codling moth larvae has been widely studied [13, 14]. It is influenced by many factors including temperature, humidity, tree height and size and so on. It has been shown that the damage inflicted on the cultures of Apple is most often located at the level of the borders [15]. In the present work, we are interested in understanding codling moth population dynamics in three varieties of Apple (*Malus domestica* Borkh.). Thus, we seek to identify the factors that influence the infestation of the fruit of these three varieties. In other words, we tried to determine the most infested parts of the three studied apple varieties.

MATERIALS AND METHODS

Studied Species

Cydia pomonella L. is a species belonging to the family of the Tortricides. It is a small Butterfly (15-20 mm). The hindwings are grey Ashy and striated thin brown lines with task Brown at the end of the wings, characteristic of the species. The life cycle of the species presents two full generations, and a third partial which individuals not affected by diapause may produce a fourth generation [16].

Plant Material

Apple tree varieties are Golden Delicious, Royal Gala and Starking Delicious. They are located in the Middle Atlas at 1400 m of altitude, in the region of Laanoucer (33°39'42.5"N 4°51'24.9"W).

Cultures are spread over an area of 10 ha, and the plants are arranged in 88 lines oriented N- S with 67 Apple trees in each row. 3.5 m distance between the lines and 1.5 m between the trees. The trees height is between 2.5 and 4 m.

Codling Moth Survey

Visual control of codling moth attacks is by counting Apple damaged by the larvae. It took place during the months of July and August, a period of the year in which codling moth attacks are frequent.

Three canopy heights are taken into consideration: bottom, middle and top. In addition, types of orientation of the tree: four canopy aspects are taken into account. Apples showing signs of codling moth larvae attack are taken into consideration in this study.

Statistical Analysis

Statistical analysis concerns the percentage of fruit attacked by codling moth larvae in the three varieties of apple and depending on the orientation and the height of each studied tree. Statistical analyses were performed with IBM SPSS Statistics 20 (SPSS, Inc.,Chicago, IL)

ISSN: 0975-8585

RESULTS AND DISCUSSION

Codling Moth Larval Infestation

Infestation by First Generation Larvae

The results of the three apple varieties fruit infestation by first generation larvae are in the Figure below:

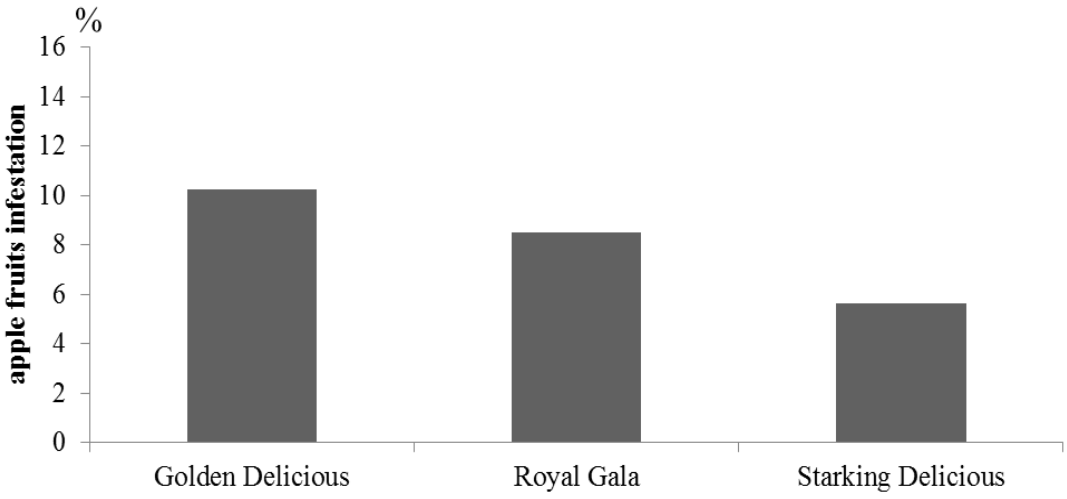

Fig. 1 : Percentage of the apple fruits infestation by first generation codling moth larvae in the studied apple varieties.

The percentage of the apple fruit infestations varies depending on the variety (ANOVA; F = 22.61, ddl = 2; P < 0.001). Royal Gala seems the most infested followed by Golden Delicious and Starking Delicious (Fig. 1).

The presence of codling moth larvae in an apple variety is related to the codling moth female choice of eggs laying behavior. This choice can be influenced by many factors related to the characteristics of the host plant. It has been shown that the codling moth females prefer the Golden Delicious variety to lay their eggs because of the large quantity of apples by Bush in this variety [17]. Moreover, many authors have pointed out that the presence of fruit is indispensable for a normal egg laying owing to the intervention of the codling moth female olfactory system α-farnesene [18-20]. Another study claims that *Cydia pomonella* females prefer to lay eggs on Golden Delicious because of its richness of many sugars and polyols [21].

Infestation by Second Generation Larvae

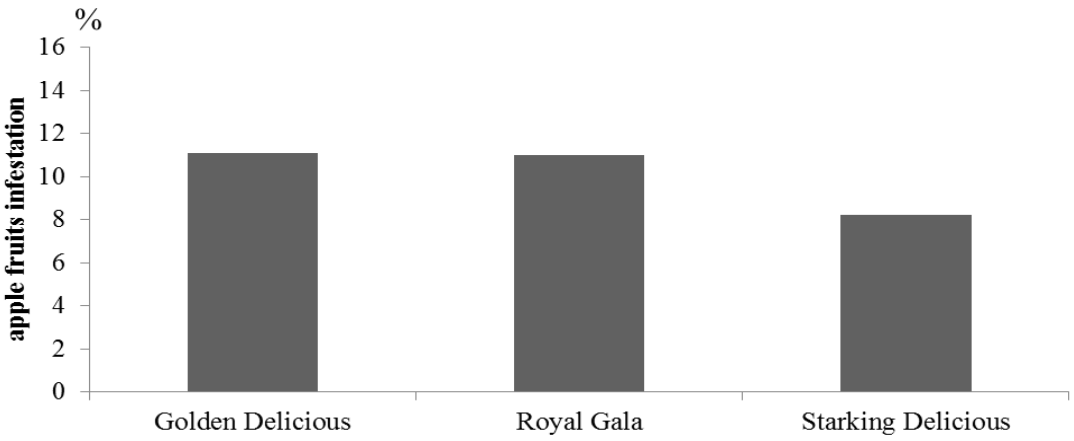

Fig. 2 : Percentage of the apple fruits infestation by second generation codling moth larvae in the studied apple varieties.

The percentage of fruit infestation by second generation larvae varies significantly depending on the variety (ANOVA; F = 12.24, ddl = 2; P < 0.001). The two varieties Golden Delicious and Royal Gala are equally infested by second generation larvae. Nevertheless, the Starking Delicious variety is the less infested either by larvae of first generation or second generation (Fig. 2).

Choosing between the two apple varieties Royal Gala and Golden Delicious by second generation larvae can be explained by the fruits organoleptic character. These two varieties are classified in the same organoleptic category: fondant and little crunchy fruits [22]. Moreover, the high concentration of polyphenols might be responsible for codling moth larvae dissuasion to penetrate apples as the skin of Starking Delicious has highly more polyphenols compared to Royal Gala and Golden Delicious [23].

Other biological parameters as the primary metabolites (sugars, amino acids, lipids, etc.) and volatile compounds in the Apple fruits can influence the attraction behavior of second generation larvae [18, 21]. As these compounds are ubiquitous in plants and their concentration differs according to the stage of phrenology, the age as well as physiological state of the plant in addition to environmental factors [24], these substances presence in the fruits at different concentrations, depending on their stage of maturity, could then influence the distribution of codling moth larvae among different Apple tree varieties.

Canopy Aspect

Infestation by First Generation Larvae

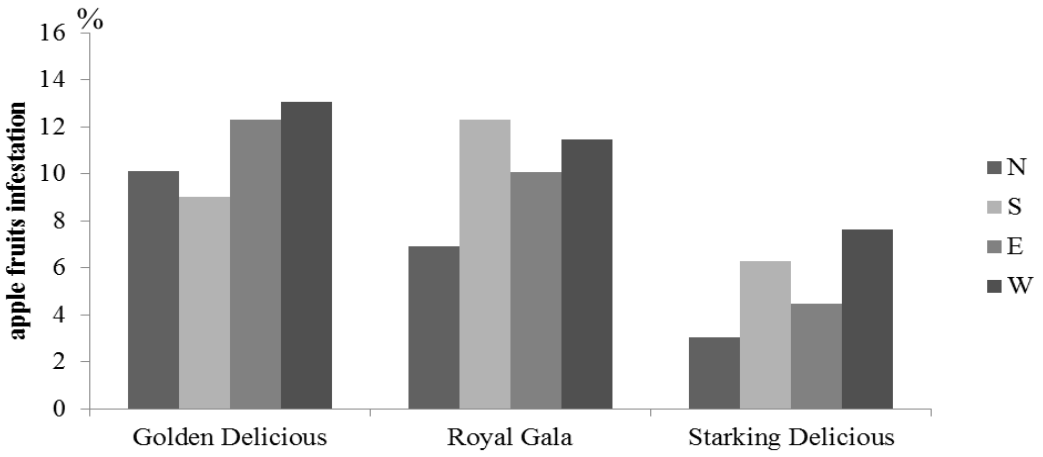

Fig. 3 : Percentage of the apple fruits infestation by first generation codling moth larvae in the studied apple varieties.

The codling moth population dynamics in the studied Orchard varies depending on many factors such as the variety of Apple, temperature, light interception, and exposure to rainfall and wind [17, 25, 26]. The first generation larvae infestation was significantly influenced by canopy aspect of the trees belonging to the three studied apple varieties. Golden delicious (Friedman test; n = 30, x2 = 8.483, P = 0.037), Royal Gala (Friedman test; n = 30, x2 = 9.680, P = 0.021) and Starking Delicious (Friedman test; n = 30, x2 = 11.305, P = 0.01). Thus, among all the studied varieties, codling moth first generation larvae prefer Golden Delicious apple fruits. Their attack rate is 10.25%, followed by Royal Gala with a percentage of attack of 8.5% and finally, Starking Delicious with 5.62% attack (Fig. 3).

In Golden Delicious variety, the West side is the most infested followed by the East side and finally, both North and South sides which are the least infested. In Royal Gala, the South and West sides of the trees seem more infested compared to the North and East sides. In Starking Delicious variety, the West side of the trees is the most infested follow by South side and finally the North side is the least infested.

The results are in line with those reported in other studies that the codling moth females prefer particular canopy aspects to lay eggs [27, 28]. Tests conducted in lab conditions on oviposioning females of codling moth showed that they avoid to lay eggs in areas where temperatures are lower [26]. In orchards, the lowest percentage of first generation codling moth larvae infestation is registered on the north side of Apple trees. It is the coolest side of the tree [29].

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Infestation by Second Generation Larvae

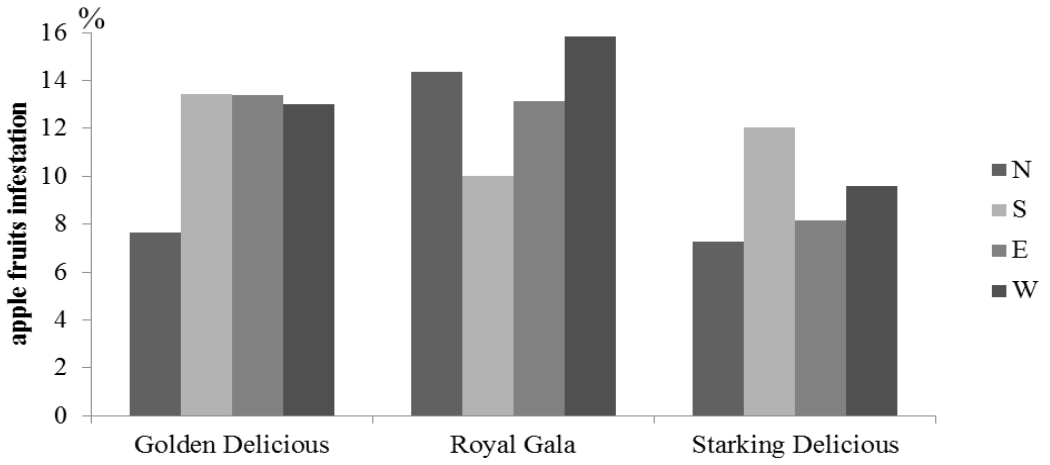

Fig. 4 : Percentage of apples infested by the second generation codling moth larvae according to canopy aspect in the Golden Delicious, Royal Gala and Starking Delicious apple varieties

Overall, the fruits of the Golden Delicious and Royal Gala varieties are the most infested by second generation codling moth larvae with an infestation percentage of 11 %. Starking Delicious variety has a fruit infestation rate of 8.23% (Fig. 4).

The Royal Gala variety has the highest infestation rate by second generation *Cydia pomonella* larvae in the West side of the tree followed by the North side, East side and finally the South side. Both East and South tend to be more infested compared to the North and West apple tree sides in Golden Delicious. In Starking Delicious variety, the South is the most infested side while the North side is the less infested.

second generation larvae avoid the tree East side of due to high temperatures received by this side of the tree during the summer season. Also, this side of the tree is exposed to the warm winds from the East in summer. The direction of the wind might be responsible to change the effect of temperature on codling moth [26].

The infestation by larvae of the second generation is highly influenced by the canopy aspect of the three studied varieties. Golden delicious (Friedman test; n = 30, x2 = 15.160, P = 0.002), Royal Gala (Friedman test; n = 30, x2 = 9.111, P = 0.028) and Starking Delicious (Friedman test; n = 30, x2 = 11.305, P = 0.01). Canopy Height

Infestation by First Generation Larvae

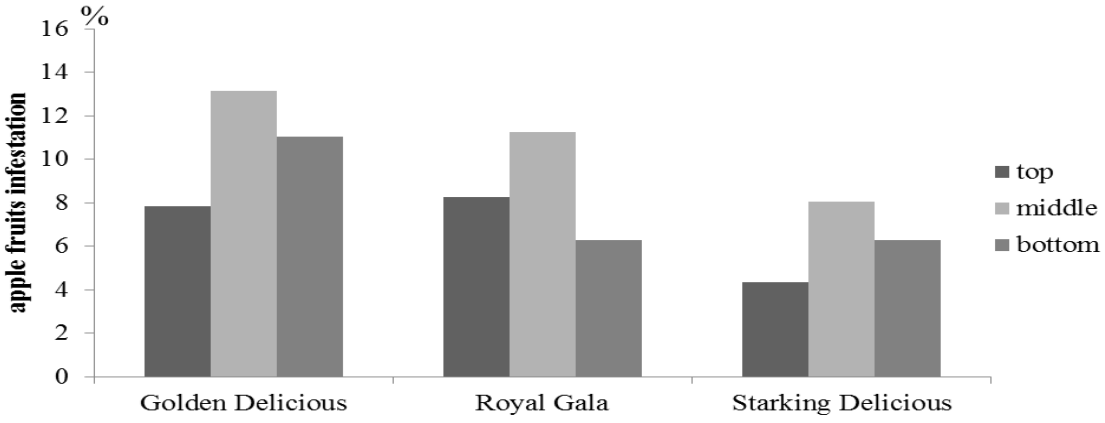

Fig. 5 : Percentage of apples infested by the first generation codling moth larvae according to canopy height in the Golden Delicious, Royal Gala and Starking Delicious apple varieties.

ISSN: 0975-8585

The results show that the canopy height influences the infestation by larvae of the first generation in Royal Gala (Friedman test; n = 30, x2 = 12.067, P = 0.002).

The highest infestation of apple fruits by first generation codling moth larvae is in the middle level of the tree. It is 13.5%, 13.1% and 8% in the three varieties Golden Delicious, Royal Gala and Starking Delicious respectively (Fig. 5).

Besides, the bottom level of the Golden Delicious is the least infested by first generation larvae. The percentage of infestation is about 7.7%. Royal Gala and Starking Delicious trees are least infested by first generation larvae on the top level. The percentage of infestation on trees top level is about 7.8% for Royal Gala and 4.35% for Starking Delicious.

The distribution of infested fruits in the Apple tree seems unchanged over the first and second generations. This distribution can be explained by many factors like temperature, light and humidity. The top and middle levels of the trees get the most of sun light. It seems that the codling moth, like other insects, avoid the parts of the tree with high humidity and prefer well ventilated and lit tree parts [30].

Previous studies have shown that codling moth females prefer to lay eggs at the top of the Apple trees [31, 32]. In contrast, other works revealed that middle level of Apple trees is the most infested by codling moth larvae [29] which supports the results of our study.

Infestation by Second Generation Larvae

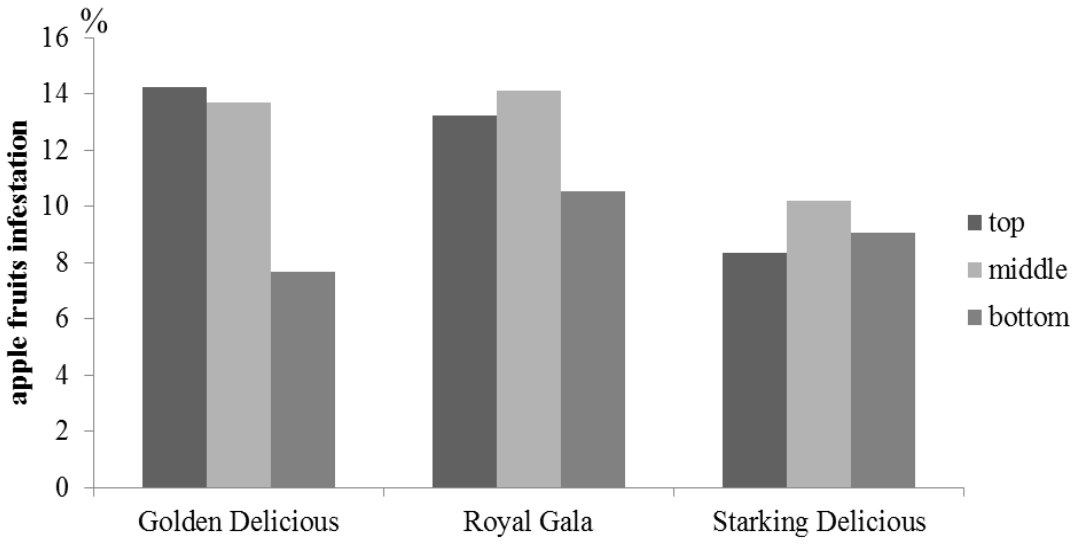

Fig. 6 : Percentage of apples infested by the second generation codling moth larvae according to canopy height in the Golden Delicious, Royal Gala and Starking Delicious apple varieties.

In figure 6, the infestation by the second generation larvae is highly influenced by canopy height in Golden Delicious (Friedman test; n = 30, x2 = 15.160, p = 0.002).

The middle level of Apple trees belonging to Starking Delicious and Royal Gala varieties are the most infested by second generation larvae with 14.2% and 12.6% respectively. In Golden Delicious, the top level is the most attacked with 7% of the damaged apples.

The bottom level of the trees is the least infested by second generation larvae in Golden Delicious (7.65%) and Royal Gala (10.5%). The lowest rate of apple infestation by second generation larvae is 9%, in Starking Delicious trees top level.

CONCLUSION

The three Apple studied varieties are highly vulnerable to attacks caused by the codling moth. The insect prefers Golden delicious variety which is the richest in sugar and polyols [21]. Starking delicious variety is the least infested by codling moth larvae. This variety has a high concentration of polyphenols in its fruits skin [23] causing a repellent effect over the codling moth insect.

In addition, the infestation of the fruits of the three studied varieties varies depending on the side of the tree. Therefore, the east side is the most infested by first generation codling moth larvae, while the North side is the least infested. It seems that warm temperatures promote the development of codling moth larvae, in cold periods of the year. The East side of apple trees is the warmest as it is well exposed to the Sun.

In summer, second generation larvae tend to flee the East side of the tree exposed to a high temperature at this time of the year. This side is receiving more Sun rays compared to the other canopy aspects.

Furthermore, the middle level of the tree is the most attacked by codling moth larvae in summer season. It's slightly exposed to the Sun. Away from the top level which is strongly exposed to the rays of Sun in summer, while the bottom level of the tree is the coolest.

From these results, we can conclude that the attack of the apple trees by the codling moth in the study area varies depending on many factors such as the variety and exposure of the tree to the sun as well as the position of the fruit depending on the height of the tree. The percentage variation of fruits larval infestation in the three studied varieties of Apple enabled us to highlight the codling moth larvae dynamic which is very influenced by the apple variety and the temperature of the fruit as well as its sun exposition.

ACKNOWLEDGMENTS

The authors are thankful to apple orchard owners for the use of orchards in conducting field research work.

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