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Codling moth management by low doses of sugars on ‘Royal Gala’ apple trees

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Abstract: Codling moth (CM) is a key pest in apple orchards in Algeria. Its control is difficult because of its ability to develop resistance to pesticides. Besides, concern about the safety of these pesticides for human health and the environment has led to regulatory actions that have reduced the availability of these products to growers. Thus, the use of eco-friendly alternative methods is encouraged. In this context, foliar spraying using fructose (100 ppm) and glucose (100 ppm) against CM larval stages on 'Royal Gala' apple, compared to the control and insecticide (Deltamethrin), was assessed in an orchard located in Beni Fedhala province (Batna-Algeria). The obtained results confirmed that the spraying of glucose and fructose increased the percentage of healthy fruits at harvest, the percentages of healthy fallen fruits and the total healthy fruits. Further, the number of diapausing larvae in corrugated cardboard banding was reduced. In addition, our study shows that the number of chrysalis was significantly lower and different from the number of male and female larvae, which are identical.

Key words: Codling moth, glucose, fructose, Deltamethrin, 'Royal Gala'.

Uravnavanje jabolčnega zavijača z majnimi odmerki sladkorjev na jablanah 'Royal Gala'

Izvleček: Jabolčni zavijač (CM) je ključni škodljivec v sadovnjakih jablan v Alžiriji. Njegovo uravnavanje je težavno zaradi njegove sposobnosti razvoja rezistence na pesticide. Poleg tega je skrb zaradi škodljivosti pesticidov ljudem in okolju privedla k načinom uravnavanja, ki zmanjšujejo dostopnost pesticidov sadjarjem. Vzpodbujane so okolju prijazne metode uravnavanja škodljivca. V tem kontekstu je bilo opravljeno foliarno škroplenje s fruktozo (100 ppm) in glukozo (100 ppm) za zatiranje jabolčnega zavijača v larvalnem štadiju v nasadu jablan 'Royal Gala', v primerjavi s kontrolo in uporabo insekticida (Deltamethrin), v sadovnjaku province Beni Fedhala (Batna-Algeria). Dobljeni rezultati so potrdili, da je škropljenje z glukozo in fruktozo povečalo odstotek zdravih plodov ob obiranju, kot tudi odstotek odpadlih zdravih plodov in celokupni delež zdravih plodov. Zmanjšalo se je tudi število mirujočih gosenic v pasteh iz valovite lepenke. Dodatno je raziskava pokazala, da se je število bub zmanjšalo in da je bilo različno od sicer identičnih moških in ženskih gosenic.

Ključne besede: jabolčni zavijač, glukoza, fruktoza, Deltamethrin, 'Royal Gala'.

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1 INTRODUCTION

Cydia pomonella (Linnaeus, 1758) causes large economic losses for the fruit yield in Algeria. Codling moth resistance to many insecticides has been observed in several areas (Bouvier et al., 2001; Sauphanor et al., 2006; Charmillot and al., 2007; Whalon et al., 2008; Rodríguez et al., 2011 et 2012; Pajac et al., 2019). Currently, it is essential to design eco-friendly control systems. The concept of exogenous application of sugars on apple trees to reduce the damage of *C. pomonella* in commercial orchards has shown increased interest in several countries (France, Italy, Greece, and Algeria) with an efficacy percentage of 40–59 % (Derridj et al., 2011). The studies of Lombarkia (2002) and Lombarkia et al. (2008) and (2013) testing the link between six metabolites (glucose, fructose, sucrose, sorbitol, quebrachitol, and *myo*-inositol) and *C. pomonella* egg-laying behavior to reduce the damage, in addition, Tiffrent and Lombarkia (2022a) showed that the glucose and fructose treatments significantly reduced the number of eggs led to similar results as for the reference chemical treatment during the first and third generation flights on 'Golden Delicious' and during the fourth flight on 'Royal Gala'. Furthermore, according to Tarkowski et al. (2019), the concept of "sweet immunity" postulates that sugar metabolism and signaling influence plant immune networks.

The objective of this study was to determine the effect of the foliar application of sugars specifically, fructose alone and glucose alone, and insecticide compared with a control in apple fruit orchard and to design alternative eco-friendly control systems to substitute conventional chemical programs.

2 MATERIALS AND METHODS

2.1 STUDY SITE AND TREATMENTS

'Royal Gala', is a highly esteemed variety famed for its sweet, crisp apples. According to the Food and Agriculture Organization of the United Nations (FAO), the major apple cultivars can be roughly divided into either red-colored bearing fruit, such as 'Red Delicious', 'Fuji', and 'Royal Gala', among others, and yellow/green-colored bearing fruits, such as 'Golden Delicious', 'Granny Smith', and 'Orin' (Korbon, 2021). 'Golden Delicious' and 'Royal Gala' are the preferred apple varieties for juice production due to their good balance between sweetness, bitterness, and aroma compounds (Ramadan and Farag, 2022).

The experiment was carried out in 2021 in a 'Royal Gala' apple orchard (35°21'21,6" N, 006°01' 16,5" E) located in Batna province (eastern Algeria). The treatments were adjusted in a randomized Latin square with four repetitions against *C. pomonella*. All four modalities are then distributed within each of the four plots, and each plot has three trees. The studied orchard was managed under common practices of the region. It had a surface area of 2.5 ha (three apple varieties, apricot, peach, plum, and nectarine trees) with 450 'Royal Gala' apple trees. The trees were 11 years old, and the plant spacing was 4 m × 4 m.

The treatments were applied using an electrical pressure sprayer (12 V-12 Ah) with a capacity of 16 l. The tested modalities were fructose, glucose, and insecticide Decis (its active ingredient is Deltamethrin), in addition to the unsprayed control. The tested treatments, their doses, and periods of application are reported in Table 1.

2.2 DAMAGE ASSESSMENTS

The following variables were measured; the percentage of healthy fruit at harvest, the percentages of healthy fallen fruits and the percentage of total healthy fruits. All variables where based on the total number of fruits produced per tree.

2.3 COUNTING DIAPAUSING LARVAE

To collect diapausing larvae of the CM, all trees of the four plots were selected, a strip of corrugated cardboard (20 cm wide) was placed around the trunk of each tree and at a height of 20 cm from the ground, installed between the mid-April and the end of September, and the captured diapausing larvae were counted, making it possible to distinguish between male larvae, female larvae, and chrysalis. According to Kuyulu and Genc (2019), the fifth instar larvae were used to determine the sex of the

Table 1: Tested treatments, their doses, and periods of application

Treatments	Doses	Periods of application
Control (Untreated)	Control (Untreated)	The morning treatments (sugars and insecticide) were carried out every 20 days throughout the season from the flowering end until harvest (Derridj et al., 2012).
Fructose (Fluka Biochemika)	10 g 100 l^{-1} (100 ppm)	
Glucose(Fluka Biochemika)	10 g 100 l^{-1} (100 ppm)	
Decis 25 EC 25 g l^{-1} Deltamethrin (Bayer)	(0,5 l) 1000 l^{-1}	

larvae. Male larvae had two unique dark spots near the end of the dorsal side. So the distinction is based on the presence or absence of these dark spots (the male genital system), clearly visible on the dorsal side.

2.4 STATISTICAL ANALYSIS

The statistical procedure for the obtained data was performed with SPSS software. The means between each variable, percentage of healthy fruit at harvest, percentage of healthy fallen fruits and the percentage of total healthy fruits, number and type of diapausing larvae were compared by ANOVA on a rank test, followed by post hoc analysis using Fisher's and Tukey's tests or the Kruskal-Wallis test. A P-value of 0.05 was used to establish statistical differences in all tests.

3 RESULTS AND DISCUSSION

3.1 PERCENTAGE OF HEALTHY FRUITS AT HARVEST

Foliar sprays of glucose have induced a significant increase in the percentages of healthy fruit at harvest compared to the untreated control. On the other hand, fructose generated a percentage of healthy fruits at harvest similar to that of the insecticide. The analysis of variance (Kruskal-Wallis test) ($p < 0.05$) identifies three groups: control (51.18 ± 2.57 %), glucose (78.18 ± 0,80 %), followed by the spraying of fructose and insecticide (82.91 ± 0.52 % and 83.76 ± 0.99 %, respectively) (Figure 1).

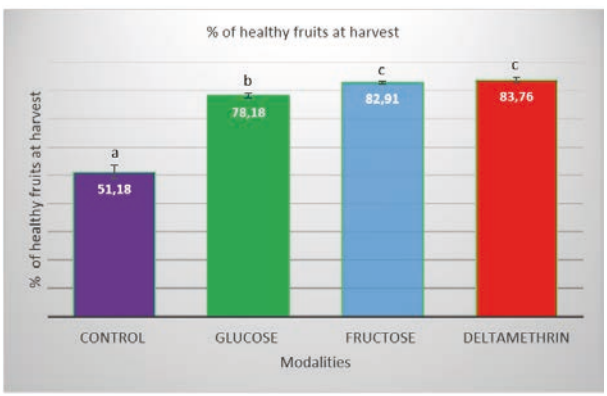

Figure1: Percentage of healthy fruits at harvest in the apple orchard (n = 12) under different modalities (control, fructose, glucose, insecticide). Different letters indicate a significantly different percentage of healthy fruits at harvest ($p < 0.05$).

3.2 PERCENTAGE OF HEALTHY FALLEN FRUITS

The spraying of glucose and fructose induced a significant increase in the percentages of healthy fallen fruits compared to the untreated control, and their percentages are similar to those of the insecticide. The analysis of variance (ANOVA) followed by the Tukey test ($p < 0.05$) identified two groups: control (41.41 ± 0.79 %), followed by the spraying of glucose, fructose, and insecticide (64.89 ± 2.24 %), 64.87 ± 2.04 % and 62.21 ± 2,55 % respectively (Figure 2).

3.3 PERCENTAGE OF TOTAL HEALTHY FRUITS

Foliar sprays of glucose have increase significantly the percentage of total healthy fruits and fructose generated a percentage of total healthy fruits similar to that of the insecticide. The analysis of variance (ANOVA) followed by the Tukey test ($p < 0.05$) classified the tested treatments in three group: control (47.08 ± 1.48), glucose (75.27 ± 0.85 %), fructose and insecticide (78.73 ± 0.64 %, 80.93 ± 1.01 % respectively (Figure 3).

3.4 COUNTING THE NUMBER OF DIAPAUSING LARVAE

The spraying of glucose and fructose led to a result similar to that of the insecticide. It caused a significant decrease in the number of diapausing larvae compared to the untreated control. The analysis of variance (Kruskal-Wallis test)($p < 0.05$) identified two groups: control (56.92 ± 2.73 %), followed by the spraying of glucose,

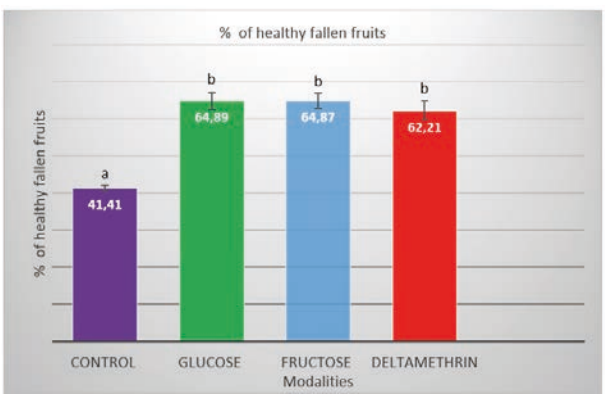

Figure 2: Percentage healthy fallen fruits in the apple orchard (n = 12) under different modalities (control, fructose, glucose, insecticide). Different letters indicate a significantly different percentage of healthy fallen fruits ($p < 0.05$).

fructose, and insecticide (6.17 ± 1.58 %), 10.08 ± 2.58 %, and 4.75 ± 0.82 %, respectively (Figure 4).

3.5 COUNTING THE NUMBER OF MALE AND FEMALE LARVAE AND CHRYSALIS

The number of male and female larvae was not significantly different. Furthermore, the number of chrysalis was significantly lower and different in comparison to the number of male and female larvae. The analysis of variance (Kruskal-Wallis test) (p <0.05) revealed two groups: the number of male and female larvae (7.06 ± 1.15 % and 11.5 ± 2.02 %, respectively), followed by the number of chrysalis, 0.92 ± 0.27 % (Figure 5).

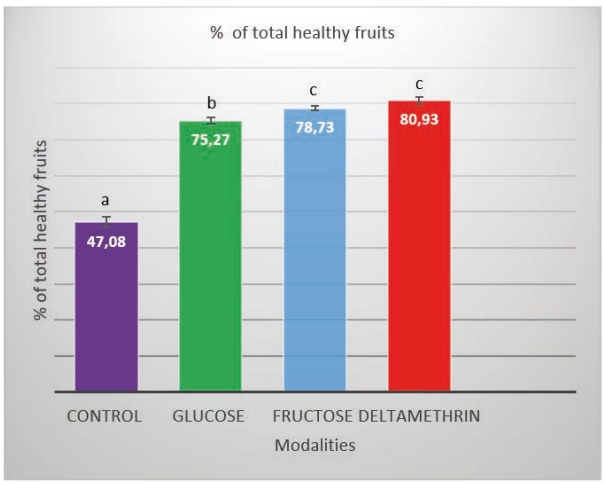

Figure 3: Percentage of total healthy fruits in the apple orchard (n = 12) under different modalities (fructose, glucose, insecticide). .

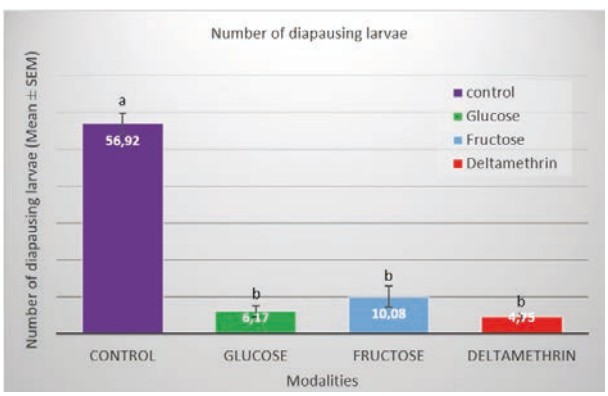

Figure 4: Number of diapausing larvae (n = 12) under different modalities (control, fructose, glucose, insecticide). Different letters indicate a significantly different number of diapausing larvae (p < 0.05).

It is apparent from our findings, that the spray of exogenous foliar application at doses of 100 ppm for glucose and fructose has increased the percentage of healthy fruits and reduced damage compared to the control. These results are partly similar to the results of some previous experiments conducted on 'Starkrimson', 'Golden Delicious', and 'Royal Gala' varieties (Abdesslem, 2016; Arnault et al., 2015 and 2016; Meradi, 2015; Nasri, 2015; Tiffrent and Lombarkia, 2021). As discussed in details in the article of Tiffrent and Lombarkia, (2022b) and their finding that the 'Royal Gala' variety was better suited than the other varieties to the concept of exogenous foliar application at doses of 100 ppm for glucose and fructose, because they have increased the percentage of healthy fruits and reduced the percentage of damaged fruits at harvest (percentage of damaged fruits: 15.27 % and 16.45 %, respectively, compared to the control 76.99 %). The same authors mentioned that the percentage of fallen and damaged fruits at harvest was 31.93 % and 19.16 %, respectively, compared to the control (32.54 %); while, the percentage of healthy fallen fruits was 68,07 % and 80,84 % respectively, compared to the control 67,46 %, also, the spraying of glucose and fructose induced a significant decrease in the number of diapausing larvae compared to the untreated control (glucose 10.08 %, fructose 06.67 %, and control 34.50 %, respectively). Thus, the present study has confirmed the promising results recorded for this variety (Royal Gala).

Meradi (2015) has demonstrated in her study on the 'Starkrimson' variety that that the number of males was more important than that of the female larvae, and that of the chrysalis was lower. Walters et al. (2013) explained that induced resistance is a host response; its expression under field conditions is likely to be influenced by a number of factors, including the environment, genotype, crop

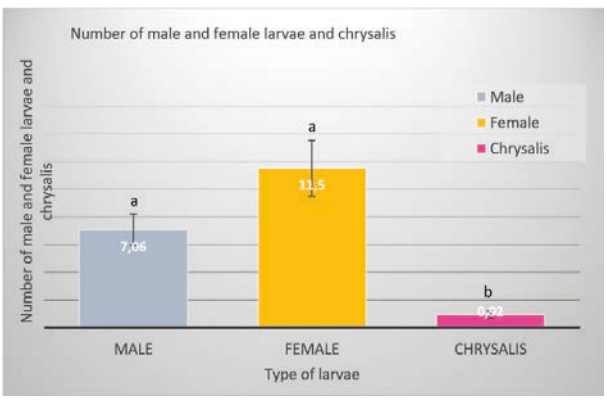

Figure 5: Number of male and female larvae and chrysalis (n = 12) under different modalities (control, fructose, glucose, insecticide). Different letters indicate a significantly different number of diapausing larvae (p < 0.05).

nutrition, and the extent to which plants are already induced.

4 CONCLUSION

In conclusion, our study has shown that codling moth can be effectively managed by using exogenous applications of sugars to reduce damages. However, sugars can induce resistance to *C. pomonella*. These results open up new methods of integrated pest management. In the future, it may be desirable to investigate the effects of foliar application of single sugars on the 'Royal Gala' variety.

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