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Effect of foliar application of glucose and fructose to reduce codling moth (*Cydia pomonella* [L., 1758]) damages on apple orchard

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Abstract: The apple is a dominant crop in Batna region and codling moth (CM) (*Cydia pomonella*) pressure is constantly very high. In this study, foliar application of single sugars is proposed as a novel control strategy, in an orchard located in Beni Fedhala (province of Batna-Algeria). The effect of spraying fructose (100 ppm), glucose (100 ppm), and insecticide (Deltamethrin) was tested against CM larval damages on the Royal Gala variety. This research showed that CM own four generations in this region. The spraying of glucose alone, fructose alone strongly reduced the percentage of damaged fruits with a very important value of Abbott's efficacy. In addition, fructose and insecticide induced a significant decrease in the percentages of fallen and damaged fruits. Besides, the use of fructose, glucose and the insecticide has significantly reduced the number of diapausing larvae in corrugated cardboard banding. Foliar application of sugars is a completely innovative way in the field of plant protection. These results open new crop management methods.

Key words: *Cydia pomonella,* glucose, fructose*,* Deltamethrin

Učinek foliarnega nanosa glukoze in fruktoze za zmanjšanje škod po jabolčnem zavijaču (*Cydia pomonella* [L., 1758]) v nasadu jablan

Izvleček: Jablana je dominatna sadna vrsta na območju Batne in napad jabolčnega zavijača je stalno zelo velik. V raziskavi je bil uporabljen nanos posameznih sladkorjev kot novi način uravnavanja škodljivca v sadovnjakih na območju Beni Fedhala (provinca Batna-Alžirija). Preiskušeno je bilo škropljenje s fruktozo (100 ppm), glukozo (100 ppm) in insekticidom (Deltametrin) glede na poškodbe, ki so jih ličinke jabolčnega zavijača povzročile na sorti Royal Gala. Raziskava je pokazala, da ima jabolčni zavijač na tem območju štiri generacije. Škropljenje samo z glukozo ali samo s fruktozo je močno zmanjšalo delež poškodovanih plodov s pomembno vrednostjo Abbottove učunkovitosti. Dodatno je obravnava s fruktozo in insekticidom vzpodbudila značilno zmanšanje odstotka odpadlih in poškodovanih plodov. Poleg tega je uporaba fruktoze, glukoze in insekticidov značilno zmanjšala število bub v lovilnih trakovih na deblu jablan. Foliarni nanos sladkorjev je popolnoma nov pristop na področju varstva rastlin. Izsledki te raziskave odpirajo nove metode pri gojenju rastlin.

Ključne besede: *Cydia pomonella*; glukoza; fruktoza; Deltametrin

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1 INTRODUCTION

The codling moth (*Cydia pomonella* [L., 1758]) (CM) is one of the greatest hindrances to apple production in Algeria. The adoption of environmentally acceptable pest control management has increased in the face of dwindling conventional control methods. Sugars not only fuel cellular carbon and energy metabolism but also play pivotal roles as signaling molecules, in plants, different sugar signals are responsible to modulate growth, development, and stress responses (Rolland et al., 2006). The existence of Lepidoptera species is dependent on the site that the female chooses to lay the eggs since the hatching larvae are less mobile (Derridj et al., 2012). The composition of a metabolite blend on the leaf surface consisting of glucose, fructose, sucrose, sorbitol, quebrachitol, and *myo*-inositol is one of the factors that could explain the variation of the intensity of egg-laying by the moth from one cultivar to another (Lombarkia et al., 2013). The studies of Lombarkia (2002) and Lombarkia et al., (2008 and 2013) were tested the link of these six metabolites on *C. pomonella* egg-laying behaviour to reduce the damage. Furthermore, other researchers (Derridj et al., 2011, Arnault et al., [2015, 2016]) have shown an increased interest in the concept of exogenous application of sugars on apple trees to reduce the damage of *C. pomonella* in commercial orchards in several countries (France, Italy, Greece, and Algeria).

As for all agricultural crops, plant protection problems such as pests and diseases are the major factors decreasing apple production. CM cause economical losses in orchards in the Batna region, the interest in strategies in order to keep the pest populations at an economically negligible level is consequently increasing.

In this context, the present research proposed exogenous application of sugars specifically fructose alone and glucose alone on apple trees. A main objective is the assessment in the orchard of the impact of low doses of sugars on fruit damages in comparison to the untreated control, for developing a new environmentally acceptable control method.

2 MATERIAL AND METHODS

This research was conducted at the Batna region, eastern Algeria, (35°21′21,6″ N, 006°01′ 16,5″ E) and in a Royal Gala apple orchard. Four apple plots test treatments of *C. pomonella*. The treated orchard (surface of 2 ha, 9 years old) was managed under common practices of the zone.

One attractive sex pheromone trap type Russell IPM was used to follow the pest dynamics and population of CM during 2019 and 2020, placed at eye level, trapping took place between 17th March to 04th September 2019 and 17th March to 04th September 2020, the observations were carried out every 3 days. The total number of captured moths was counted.

2.1 TREATMENTS

The orchard was divided into four plots adjusted in a randomized Latin square with four repetitions and each plot has three trees, the modalities tested were fructose at 100 ppm (10 g 100 l^{-1}), glucose at 100 ppm (10 g 100 l^{-1}) and insecticide Decis 25 EC (25 g l^{-1} Deltamethrin) at (0.5 l) 1000 l^{-1} dose, in addition to the unsprayed control modality, The treatments were applied using an electrical pressure sprayer (12 V-12 Ah), capacity 16 l. (Fructose and glucose are produced by Fluka Biochemika and Decis by Bayer).

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).

2.2 DAMAGE ASSESSMENTS

According to the Abbott's formula, T0 – Tt / T0 × 100 (where T0 is the percentage of infested fruits in the untreated plots and Tt is the percentage of infected fruits in the treated plots), the percentage of fruit damaged at harvest, efficiency of treatments at harvest and percentage of fallen and damaged fruits were measured.

2.3 COUNTING DIAPAUSING LARVAE

The larva at the end of its growth (fifth instar larvae) overwinters in a cocoon (diapausing larvae) in the crevices of the trunk. The sequestration of diapausing larvae by bandaging tree trunks provides a simple and effective means to estimate the CM population, a strip of corrugated cardboard (20 cm wide) was placed around the trunk of all trees, of the four plots and at a height of 20 cm from the ground, installed between mid-April to the end September, the captured diapausing larvae were counted.

2.4 STATISTICAL ANALYSIS

All analyses were performed using SPSS software v 2016. The means of each variable (percentage of fruit damaged at harvest, efficiency Abbott of treatments at

harvest and percentage of fallen and damaged fruits, number of diapausing larvae), were compared by ANOVA on ranks test, followed by post hoc analysis using Fisher's and Tukey's tests or Kruskal-Wallis test. A P-value of 0.05 was used to establish significance in all tests.

3 RESULTS AND DISCUSSION

3.1 SEXUAL TRAPPING OF ADULTS

Two trials were conducted during the 2019 and 2020 seasons, where there are four full codling moth generations (Table 1).

The determination of generations is based on the following principle described by Hmimna and Iraqui (2015), the division a significant and stable increase in catches, followed by a sufficiently long inter-flight (± 30 days) with few catches, indicates a nascent or finishing flight comparable to the start or the end of a generation.

In Algeria, several studies revealed that the CM has two at four generations depending on the climate conditions and the regions. For instance, Soltani et al. (1986), has been stated that CM in quince orchard has four generations while the fourth is partial. Furthermore, Abdesselam (2016) reported two generations of CM in Inoughissen (Batna) and Meradi (2015) found that CM produced three generations in the season. Besides, Tiffrent and Lombarkia (2021) indicated that CM in Batna province, has four generations in the season on the Golden Delicious variety.

3.2 DAMAGE ASSESSMENTS AND TREATMENTS EFFICACY

Foliar sprays of fructose and glucose reduced significantly the percentage of fruit damaged at harvest compared to the control, the analysis of variance (Kruskal-Wallis test), ($p < 0.05$) identifies three groups, control (76.99 ± 1.97 %, a group), glucose and fructose (15.27 ± 1.06 % and 16.45 ± 0.59 % respectively (b group), followed by the spraying of the insecticide with 10.97 ± 0.56 % (c group) (Figure 1).

The Abbott efficiency at harvest of glucose treatments is 80.25 % and fructose generates an average percentage efficiency of 78.58 % compared to the insecticide 85.64 %. The analysis of variance (ANOVA) followed by the Tukey test ($p < 0.05$) identifies two groups (Table 2).

On the other hand, the spraying of fructose alone and the insecticide induced a significant decrease in the percentages of damaged and fallen fruits compared to the untreated control and glucose alone. The analysis of variance (ANOVA) followed by the Tukey test ($p < 0.05$) identifies three groups, control and glucose 32.54 ± 1.25%, 31.93 ± 1.16 % respectively (a group), fructose 19.16 ± 0.91 %, (b group) and insecticide 09.78 ± 0.8 % (c group) (Figure 2).

Moreover, the spraying of glucose, fructose and the insecticide induced a significant decrease in the number of diapausing larvae compared to the untreated control. The analysis of variance (Kruskal-Wallis test), ($p < 0.05$) identifies two groups, control 34.50 ± 2.55 % (a group), glucose 10.08 ± 1.55 %, fructose 06.67 ± 1.67 % and insecticide 08.25 ± 2.22 % respectively (b group) (Figure 3).

By drawing on the concept of the exogenous foliar application of a single sugar can induce plant resistance to the pest, Arnault et al. (2015) indicated that on Granny Smith variety, sprays of fructose at 100 ppm in combination with organo-phosphorus (OP) and insect growth

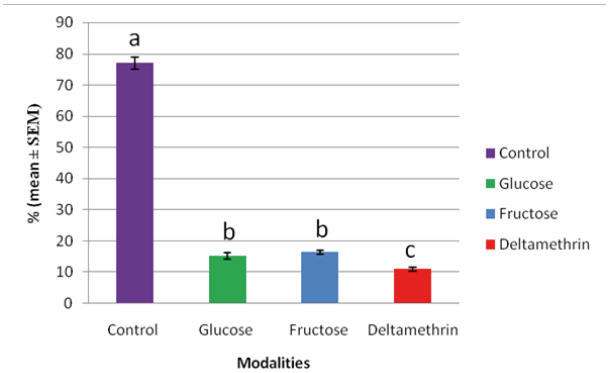

Figure 1: Percentage of damaged fruits at harvest in apple orchard (n = 12) on different modalities (control, fructose, glucose, insecticide). Different letters indicate a significantly different percentages of fruit damaged at harvest at $p < 0.05$

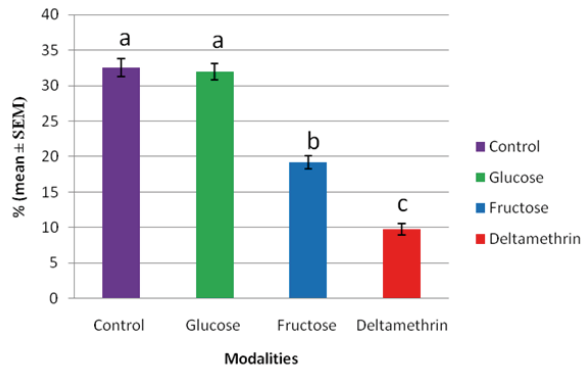

Figure 2: Percentage of fallen and damaged fruits in apple orchard (n = 12) on different modalities (control, fructose, glucose, insecticide). Different letters indicate a significantly different percentage of fallen and damaged fruits at $p < 0.05$

Table 1: The number of catches of *C. pomonella* adult males during the four generations

Dates of trapping	Traps G1		Dates of trapping	Traps G2		Dates of trapping	Traps G3		Dates of trapping	Traps G4	
	2019	2020		2019	2020		2019	2020		2019	2020
20/03	1	1	22/04		10	16/05		10	12/07		06
23/03	0	0	25/04		18	19/05		17	15/07		14
26/03	1	1	28/04		20	22/05		10	18/07		16
29/03	0	0	01/05		40	25/05		10	21/07		10
01/04	1	0	04/05	10	50	28/05	03	11	24/07		08
04/04	1	4	07/05	14	48	31/05	19	10	27/07		10
07/04	2	6	10/05	31	52	03/06	25	11	30/07	5	11
10/04	0	7	13/05	13	27	06/06	09	13	02/08	13	13
13/04	0	23	16/05	13		09/06	26	13	05/08	21	18
16/04	8	40	19/05	10		12/06	16	14	08/08	15	15
19/04	23	18	22/05	38		15/06	11	12	11/08	31	7
22/04	36		25/05	19		18/06	14	12	14/08	10	7
25/04	34					21/06	10	15	17/08	7	6
28/04	35					24/06	14	20	20/08	45	4
01/05	26					27/06	29	22	23/08	3	5
						30/06	80	27	26/08	2	4
						03/07	75	20	29/08	2	4
						06/07	70	14	01/09	20	4
						09/07	42	13	04/09	09	5
						12/07	20				
						15/07	24				
						18/07	24				
						21/07	10				
						24/07	14				
						27/07	17				

regulator (IGR) have significantly reduced the percentage of damaged fruits by CM at harvest compared to the OP and IGR alone (6.5 %, 10 %); and the efficiency is improved by 35 %. In 2013, 2014, at organic orchards study; Arnault et al. (2015) demonstrated that, the foliar applications of fructose to 100 ppm could reduce CM damage by 55 % on the Gala variety. In addition, Arnault et al. (2016) showed that fructose 100 ppm reduced the damage of CM in four commercial apple orchards from 2013 to 2014 in Algeria and France, and the results revealed an efficacy Abbott of 48.9 % and the average percentage of infested fruits was 8.1 % which was significantly lower compared to the untreated modality (23.8 %).

Similarly, previous studies have demonstrated the potential of foliar application of sucrose in micro-doses to control *C. pomonella* performed in the Batna region support our findings.

For instance, Meradi (2015) has demonstrated in her

Table 2: Percentage of Abbott efficiency at harvest in apple orchards (n = 12) on different modalities (fructose, glucose, insecticide)

Treatments	% Abbott efficiency (Mean + SEM*)
Glucose 100 ppm	80.25 % ± 1.18 a
Fructose 100 ppm	78.58 % ± 0.86 a
Insecticide (Deltamethrin)	85.64 % ± 0.85 b

* Values indicated with different letters are significantly different at $p < 0.05$

study conducted on the Starkrimson variety, that fructose 100 ppm has reduced the percentage of fallen and damaged fruits compared to the control (56.0 %and64.0 % respectively), and the Abbott effectiveness at harvest was 31.71 %. While in the study of Abdesselam (2016) on the Golden Delicious variety, sprays of fructose at 100 ppm and glucose at 100 ppm significantly reduced the percentage of fallen and damaged fruits at harvest (92.28 %, 67.47 % respectively) compared to the control (92.28 %); the Abbott effectiveness at harvest were 69.06 % and 8.28 % respectively. In addition, Tiffrent and Lombarkia (2021) have specified that in the study leading on Golden Delicious variety, Abbott's efficiency at harvest obtained for fructose 100 ppm and glucose 100 ppm were 15.54 % and 23.75 % respectively. Whereas in the study of Nasri (2015) on the Royal Gala variety the use of glucose at 10 ppm has significantly reduced the percentage of fallen and damaged fruits compared to the control (24.77 %) and (54.19 %) respectively, and the Abbott effectiveness at harvest was 11.86 %.

This finding, apparent from these studies while preliminary, suggests that the Royal Gala variety was better suited to the concept of the exogenous foliar application at doses of 100 ppm for glucose and fructose in our current study, they have reduced the percentage of fallen and damaged fruits at harvest (31.93 %, 19.16 % respectively) compared to the control (32.54 %); the Abbott effectiveness at harvest was 80.25 % and 78.58 % respectively.

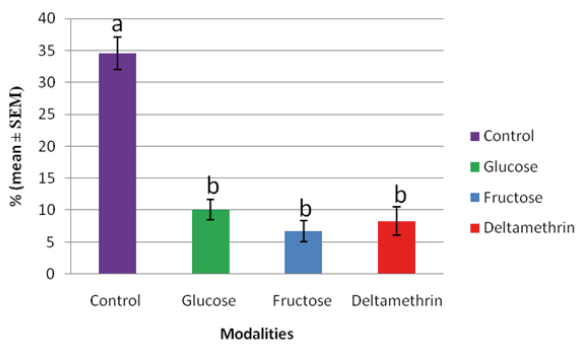

Figure 3: Number of diapausing larvae (n = 12) on different modalities (control, fructose, glucose, insecticide). Different letters indicate significantly different number of diapausing larvae at $p < 0.05$

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 nutrition and the extent to which plants are already induced.

The overwintering is often a critical part of the insect life-cycle; CM overwinters as a diapausing fifth instar larva. As mentioned in our results, the influence of the spraying of glucose and fructose in diapausing larvae has been demonstrated. These results are in agreement with the findings of other studies. Meradi (2015) reported that treated plots with fructose 100 ppm showed a significantly reduced number of CM diapausing larvae compared to the control, and Nasri (2015) proved that glucose 10 ppm decreased significantly the number of diapausing larvae compared to the control (untreated). Consequently, with this decrease in the number of diapausing larvae, we predict and estimate a low population of adults in the next generation and allow adapted the protection strategy for the following year.

4 CONCLUSION

Based on the obtained results, it can be concluded that the exogenous application of sugars can reduce codling moth damage and small molecules such as glucose and fructose can induce resistance to *C. pomonella* by foliar applications. Possible future studies using the same trials on Royal Gala variety is proposed to confirm these findings for the development of biocontrol strategies.

5 REFERENCES

Abdesslem Z. (2016). *Utilisation des sucres et virus de la granulose pour la lutte contre le carpocapse Cydia pomonella L. (Lepidoptera, Tortricidae) en verger de pommier situé dans la région d'Inoughissen (Wilaya de Batna), Magister dissertation*, Agronomic institute, University of Batna, 79 p.

Arnault I., Bardin M., Ondet S., Furet A., Chovelon M., Kasprick A. C., Marchand P., Clerc H., Davy M., Roy G., Romet L., Auger J., Mançois A., Derridj S. (2015). Utilisation de micro-doses de sucres en protection des plantes. *Innovations Agronomiques*, *46*, 1-10.

Arnault I., Ondet S. J., Lombarkia N., Warlop F., Derridj S. (2016). Preliminary results of foliar applications of fructose to reduce codling moth *Cydia pomonella* L.

(Lepidoptera, Tortricidae) damages on apple tree in organic farming. *In Ecofruit. 17th International Conference on Organic Fruit-Growing: Proceedings, 15-17 February*, Hohenheim, Germany, pp. 196-199.

Derridj S., Arnault I., Nicholas A., Birch E., Elad Y., Lombarkia N., Couzi P., Pierre P., Auge J. (2011). Les sucres solubles, une opportunité pour l'agriculture durable. *Phytoma- la Défense des Plantes, 640*, 10-14.

Derridj S., Lombarkia N., Garrec J. P., Galy H., Ferré E. (2012). Sugars on leaf surfaces used as signals by the insect and the plant: implications in orchard protection against *Cydia pomonella* L. (Lepidoptera, Tortricidae), *in Moths: Types, Ecological Significance and Control*, ed. by Cauterrucio L. Nova Science Publishers Inc., Hauppage, NY, pp. 1-38

Hmimina M., El Iraqui S. (2015). Cycle évolutif et voltinisme du Carpocapse (*Cydia pomonella* L., Lepidoptera, Tortricidae) exprimés par le piégeage sexuel et les degrés-jours dans la région d'Azrou. [Life cycle and voltinism of codling moth (*Cydia pomonella* L., Lepidoptera, Tortricidae) based on sexual trapping and degree days in Azrou region]. *Revue Marocaine des Sciences Agronomiques et Vétérinaires, 3*(2), 1.

Lombarkia N. (2002). *Influence de métabolites présents à la surface des organes du pommier sur la ponte du carpocapse: Cydia pomonella L. (Lepidoptera : Tortricidae). Application à l'étude de la résistance du pommier au ravageur*. *Doctoral dessertation*. University of Rennes 1, France. https://doi.org/10.1046/j.1570-7458.2002.00993.x

Lombarkia N., Derridj S. (2002). Incidence of apple and leaf surface metabolites on *Cydia pomonella* oviposition. *Entomologia Experimentalis et Applicata, 104*, 79-87. https://doi.org/10.1111/j.1570-7458.2008.00741.x

Lombarkia N., Derridj S. (2008). Resistance of apple trees to *Cydia pomonella* egg-laying due to leaf surface metabolites. *Entomologia Experimentalis et Applicata, 128*, 57-65.

Meradi R. (2015). *Utilisation des sucres et de virus de la granulose dans la protection des pommiers contre le carpocapse Cydia pomonella L. (Lepidoptera, Tortricidae) dans la région de Limbiridi (Wilaya de Batna)*. Magister dissertation. Agronomic institute, University of Batna, 84 p.

Nasri A. (2015). *Utilisation des sucres et virus de la granulose pour la lutte contre le carpocapse Cydia pomonella L. (Lepidoptera, Tortricidae) en verger de pommier situé dans la région d'Ain-Touta (Wilaya de Batna)*. Magister dissertation, Agronomic institute, University of Batna, 79 p.

Rolland F., Baena-Gonzalez E., Sheen J. (2006). Sugar sensing and signalling in plants: conserved and novel mechanisms. *Annual Review of Plant Biology, 57*, 675-709. https://doi.org/10.1146/annurev.arplant.57.032905.105441

Soltani N., Semir H., Djebbar M.R. (1986). Contribution à l'étude de *Cydia pomonella* (L.) (*Lepidoptera : Tortricidae*), essai comparatif des pièges et cycle évolutif à Annaba, *Annales de l'INA*, *10*(1), 196-206.

Tiffrent A., Lombarkia N. (2021). Assessement of control strategy by spraying low doses of sugars on apple orchards against *Cydia pomonella* (L.). *Acta Agriculturae Slovenica*, *117*(1), 15-20. https://doi.org/10.14720/aas.2021.117.1.1740

Walters, D. R., Ratsep, J., Havis, N. D. (2013). Controlling crop diseases using induced resistance: challenges for the future. *Journal of Experimental Botany*, *64*(5), 1263-1280. https://doi.org/10.1093/jxb/ert026