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Use of sugars as alternative to chemical control: trials carried out on thrips associated with olive tree

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Abstract: Foliar spraying of infradoses of sugars (glucose, fructose or sucrose) induces plant resistance to pests that are particularly difficult to combat. These include thrips, which can cause flower abortion, stunting and deformation of olives, resulting in significant crop losses. Randomised block trials were conducted during three years (2017 to 2019), on two cultivars Chemlal and Sigoise, in an olive grove in Batna province (Algeria), with the aim of determining the most effective dose and type of sugar on thrips populations, and to evaluate the effectiveness of combining sugar with chemical treatment, as well as the possibility of reducing the dose of the latter. The results showed that sucrose at a concentration of 100 ppm was the most effective and that the efficacy of sucrose was higher than that of glucose and fructose, on both cultivars tested. The combination of sucrose with insecticide resulted in a synergistic effect and a higher efficacy gain than sucrose alone, and that the efficacy of the combination sucrose + insecticide at low dose D1 was identical to the combination sucrose + insecticide at recommended dose D2. It is therefore possible to reduce the chemical insecticide dose while maintaining good treatment efficacy for the control of these pests.

Key words: thrips; *Olea europaea* L.; sucrose; fructose; glucose; 'Sigoise'; 'Chemlal'

Uporaba sladkorjev kot alternative kemijskemu nadzoru: poskus zatiranja tripsa na oljkah

Izvleček: Pršenje s sladkorji v majhnih koncentracijah (glukoze, fruktozeali saharoze) vzpodbuja odpornost rastlin na škodljivce, ki jih je še posebej težko zatirati. Med njimi so tripsi, ki lahko povzročajo odpadanje cvetov in deformacijo plodov oljk, kar znatno zmanjša pridelek. V obdobju treh let, 2017-2019, je bil na dveh sortah oljk, Chemlal in Sigoise, izveden naključni bločni poskus v oljčniku v provinci Batna (Alžirija), z namenom določitve najbolj učinkovitega odmerka in vrste sladkorja za uravnavanje populacije tripsa in ovrednotenje učinkovitosti kombiniranja sladkorja s kemičnimi zaščitnimi sredstvi kot možnosti njihove manjše uporabe. Rezultati so pokazali, da je bila saharoza pri koncentraciji 100 ppm najbolj učinkovita in, da je bila učinkovitost saharoze večja kot glukoze in fruktoze pri obeh preiskušenih sortah. Kombinacija saharoze z insekticidi je imela sinergetski učinek in večjo učinkovitost kot samo saharoza. Učinkovitost kombinacije saharoze in insekticida pri majhnem odmerku D1 je bila enaka kot pri kombinaciji saharoze in priporočenem odmerku insekticida D2. Iz tega sledi, da je mogoče zmanjšati odmerek insekticidov za doseganje dobre učinkovitosti pri uravnavanju teh škodljivcev.

Ključne besede: trips; *Olea europaea* L.; saharoza; fruktoza; glukoza; 'Sigoise'; 'Chemlal'

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1 INTRODUCTION

The olive tree (*Olea europaea* L.) is a typical and emblematic tree of the Mediterranean countries where it is of great importance from the economic, social and landscape point of view (Loumou & Giourga, 2003; Pappalardo et al., 2021). It represents one of the oldest and most widespread crops in Algeria. Thanks to its capacity to adapt to all bioclimatic stages, this species is present in the majority of the Algerian territory (Abdessemed et al., 2018). Nevertheless, the olive tree is susceptible to several insects' attacks and pathogens that cause a decline in olive production (Hadjou et al., 2013; Canale et al., 2019). Climatic variations in recent years have facilitated the introduction, spread and establishment of some pests and diseases in olive production (Ouyang et al., 2020; Vono et al., 2020; Ruggero, 2021). Among these pests, thrips (Thysanoptera), which are tiny sucking biting insects, having a short reproductive cycle with high reproductive potential and have a wide host spectrum including many weeds (Mound, 2018). The damage caused by food bites and viruses transmitted by certain species of thrips is mainly qualitative (discolouration, necrosis, deformation, etc.) and leads to a downgrading of the fruit and therefore to significant economic losses (Bournier, 1983). On olive trees, thrips attacks cause abortion of flowers and young fruits or result in stunted, scarred and deformed olives (Spooner-Hart et al., 2007; Phillips et al, 2020). The specific biology and behaviour of thrips makes chemical control difficult. Indeed, thrips tend to hide in flowers and buds, safe from contact insecticides; eggs inserted in the plant, and nymphs located in the soil, are also safe from treatments. In addition, they have the ability to develop resistance to insecticides (Bielza et al., 2007; Funderburk et al. 2016). Wu et al. (2018) and Reitz et al. (2020), reported that in recent years thrips have been a serious problem for crops, due to their damage and the constraints of pesticide application that make their control difficult. Faced with this situation, the use of alternative methods to chemical control remains necessary, such as the use of intercropping (Gombač & Trdan, 2014), biological control by predatory mites *Neoseiulus* spp., hemipterans *Orius* spp. (Loomans & Murai, 1997), or by predatory thrips *Aeolothrips intermedius* Bagnall 1934 (Trdan et al., 2005)

A new biocontrol method based on exogenous applications of infra-doses of soluble carbohydrates has been developed to reinforce plant immunity against certain herbivores and pathogens (Arnault et al., 2021). This is the new concept of 'Sweet Immunity' or 'sugar-enhanced defence' (Bolouri-Moghaddam & Van Den Ende, 2013; Arnault et al., 2021). Soluble carbohydrates, mainly, sucrose, glucose and fructose, are involved in many stress response mechanisms, biotic or abiotic, where they act not only as metabolites, but also as signals capable of activating signalling pathways leading to gene expression changes (Morkunas & Ratajczak. 2014; Formela-Luboińska et al., 2020). Furthermore, soluble carbohydrates sprayed at low doses can penetrate the cuticle and end up on the plant surface, constituting signals perceived by the insect through contact, then influencing its behavior and selection of the host plant to lay eggs (Derridj et al., 2011). This method induces physiological and metabolic changes in plant tissues and on the leaf surface, as well as resistance to pests (Smeekens et al., 2010)

The action of soluble carbohydrates (glucose, fructose, sucrose, trehalose) sprayed in infra doses (ppm) on the surface of cultivated plants has been studied on different crops for the control of various pests; such as *Cydia pomonella* (L., 1758) on apple, *Thrips tabaci* Lindeman, 1889 on leek, *Ostrinia nubilalis* (Hübner, 1796) on maize, *Tuta absoluta* (Meyrick, 1917), *Meloidogyne javanica* (Treub, 1885) and *Botrytis cinerea* Pers. on tomato (Ferré et al., 2008; Derridj et al., 2012; Arnault et al., 2012, 2015, 2017). These studies revealed that sugar alone has interesting effects and when combined with chemical plant protection products, it allows reducing their doses while keeping a good efficiency. Sugars activate defense pathways but not always in the same way (Arnault et al., 2021), it would however be advisable to analyse for each crop and each targeted phytophage, the most active sugar and dose. Derridj (2009), reports that the species, variety and age of the plant at the time of treatment seem to be important factors for successful resistance induction. The judicious choice of varieties and sugar should make it possible to significantly limit phytosanitary interventions against one or several pests. As no studies have been carried out on thrips associated with olive trees, this work aims to determine the most effective sugar dose (sucrose tested at different doses of 1, 10, 100 and 1000 ppm); the most effective type of sugar to use (sucrose, fructose or glucose); and whether the use of sugar alone or combined with a phytosanitary treatment (insecticide tested at recommended and reduced doses), could be an effective alternative for the control of thrips populations associated with olive tree, on two cultivars (Sigoise and Chemlal), in an olive grove located in the region of Batna (North-East of Algeria).

2 MATERIAL AND METHODS

2.1 STUDY SITE

The study was carried out in an olive grove (Table

1), located in the region of Oued Chaaba, 10 km Southeast of Batna (Northeast Algeria). This region is characterized by a semi-arid climate, hot, dry in summer and cool in winter.

Table 1: Characteristics of the experimental orchard

Geographical coordinates	35° 30′ 17″ N, 6° 4′ 40″ E
Age of the plantation	14 years
Area	7 ha
Number of trees	2000
Topography (altitude)	1082 m
Cultivar	Chemlal (55 %) Sigoise (45 %)
Plantation density	5 x 7 m
Ploughing	in winter
Irrigation	drip irrigation
Fertilisation	livestock manure
Weed control	manual/mechanical
Protection programme	no treatment

2.2 EXPERIMENTAL DESIGN

Six trials were conducted on two olive cultivars (Sigoise and Chemlal), during three years, from 2017 to 2019. Table 2 illustrates the aspects of the two studied varieties.

All trials are based on a randomised Fisher block design with four replications (4 blocks). The modalities are randomly distributed within each block and each modality (elementary plot) consists of two trees, its surface is 35 m^2 (5 m x 7 m).

In the first year of 2017, two trials were carried out on two olive cultivars (Sigoise and Chemlal), the objective was to determine the most effective sugar dose on thrips associated with the olive crop. Once identified, this dose will be used in subsequent trials. A sucrose treatment at different doses, 1, 10, 100 and 1000 ppm (= 0.1, 1, 10 and 100 g 100 l^{-1}) was compared to the control (untreated trees) and a reference treatment (insecticide Acetamiprid). Then during 2018, two trials were set up to determine the effect of sugar type on treatment efficacy. The sucrose treatment was compared to fructose and glucose, tested at the same concentration (100 ppm =10 g 100 l^{-1}), on both cultivars (Sigoise and Chemlal). In 2019, the objective of the trials was to evaluate the effect of the application of infra-doses of sugar (sucrose 100 ppm) associated or not with a chemical treatment (Acetamiprid) and also to study the possibility of reducing the dose of phytosanitary product.

Table 2: Characteristics of the studied varieties

Cultivar		Chemlal	Sigoise
Origin		local (Kabylie, North of Algeria)	local (Mascara, Northwest of Algeria)
Destination		oil	dual purpose (oil+table)
Tree	Port	upright	upright
	Vigour	high	medium
	Foliage density	medium	medium
	Rooting rate	very low	medium
Fruit	Mass (g)	1.05-2.14 (reduced)	2.74-4.79 (medium)
	Form	elongated	ovoid
	Summit	pointed	rounded
	Aspect	smooth	smooth
	Colour at maturity	black	black
Endocarp	Mass (g)	0.43-0.45 (small)	0.55-0.76 (big)
	Form	spherical	ovoid
	Summit	pointed	rounded
	Core surface	rough	rough
Leaves		long (70.19 mm)	medium (50.62 mm)
Quality (acidity %)		very good (0.171 à 0.22)	medium(0.177 à 0.34)
Oil yield (%)		18 à 24	18 à 22
Maturity		end of October	November
Resistance to drought and cold		medium	Low

2.3 APPLICATION OF TREATMENTS

The chemical insecticide (Acetamiprid) was applied when the intervention threshold was reached (10 thrips/100 shoots), which was determined by weekly monitoring (scouting) of thrips by the strike method. Shaking on shoots was carried out weekly from the beginning of flowering (April-May), on 100 actively growing shoots, selected at random in the study plot (Mandrin & Lichou, 2000, Valette, 2007). According to these authors, the monitoring of the number of thrips trapped allows to know the peak of thrips migration, key date for a chemical intervention. According to Allan and Gillett-Kaufman (2018), the peak of thrips collection on olive trees coincided with flowering. Above 10 thrips per 100 shoots, chemical treatment is justified (Valette, 2007). The chemical insecticide used in this study was Acetamiprid, which was tested at the recommended dose (D2 = 50 ml 100^{-1}l) and at a dose reduced by half (D1 = 25 ml 100^{-1}l)

The sugars (sucrose, fructose and glucose) are sprayed in infra-doses (in the ppm range), obligatorily early in the morning, before the start of photosynthesis, at the time when the intercellular spaces of the apoplast are poor in sugars, according to the method advocated by (Derridj, 2009; Derridj et al., 2011, 2012; Arnault et al., 2015, 2021), using a backpack sprayer and trying to wet the whole foliar surface. The treatment with the chemical insecticide was done just after the sugar spray.

2.4 SAMPLING METHOD

Thrips sampling during the 3 years of the study (2017 to 2019) was carried out according to the method recommended by Valette (2007), which consists in randomly shaking 25 twigs per elementary plot (2 trees/elementary plot), in the five directions (north, south, east, west and center) and from top to bottom. Thus, 100 twigs per modality were shaken during each sampling (each modality is repeated 4 times). Sampling was carried out in the morning between 8 and 10 am, 1 day (24 h) before treatment, and 1, 3, 7, 10, 14 and 20 days after treatment. Thrips dropped on the Japanese umbrella were preserved in 70 % alcohol, counted and identified in the laboratory.

2.5 STATISTICAL ANALYSIS

The results of the average number of thrips per twig and the percentages of effectiveness of the treatments were processed by analysis of variance (ANOVA) with Tukey's test using the Excel Stat 2014 software. Results were expressed as mean ± S.E. (Standard Error), and considered significantly different at $p < 0.05$.

Treatment efficacy is calculated using formula (1) of Henderson and Tilton 1955 (Valette, 2007), which determines the effectiveness of the different treatments relative to the control and relative to the pre-treatment data (To)

$$Efficacy\,\% = 100 \cdot \left[1 - \frac{Nu(t_0) \cdot NT(t)}{Nu(t) \cdot NT(t_0)}\right] \qquad (1)$$

$Nu(t_0)$: number of thrips before treatment on control; $Nu(t)$: number of thrips after treatment on control; $NT(t)$ number of thrips after treatment on treated plot; $NT(t_0)$:number of thrips before treatment on treated plot.

3 RESULTS AND DISCUSSION

3.1 PRESENTATION OF THE RECORDED SPECIES

The thrips species collected on olive trees in the study area (Table 3) are phytophagous (*F. occidentalis* was the dominant species of all species found). Indeed, the females of these species lay their eggs mainly in flower buds and flowers (Lambert, 1999). Upon hatching, the larvae feed on pollen and floral parts, causing premature flower drop. Heavy infestations cause silvering of the fruits, which dry out and fall prematurely. On olive trees, thrips cause damage to olives in the form of scars and wounds on the surface of the fruit, resulting from the sucking action of thrips, which extract the contents of the plant cells. The wounds result in the loss of the original

Table 3: Thrips species encountered in an olive grove in the Batna region

Suborder	Family	Species
Terebrantia	Thripidae	*Frankliniella occidentalis* (Pergande, 1895)
	Melanthripidae	*Odontothrips confusus* (Piesner, 1926) *Melanthrips fuscus* (Sulzer, 1776)
Tubulifera	Phlaeothripidae	*Haplothrips aculeatus* (Fabricius, 1803)

colour and the acquisition of the characteristic silvery appearance of the wounded olives (Halimi et al., 2022).

3.2 DETERMINATION OF THE SUGAR DOSE

The 1, 10, 100 and 1000 ppm sucrose modalities were compared to the reference treatment 'insecticide' and to the control. The results revealed, for both cultivars (Figure 1), a decrease in thrips populations on all treated modalities from the day after treatment (T+1). This decrease continued until the end of the experiment for the 1, 10 and 100 ppm sucrose treatments. On the other hand, the number of thrips increased from the third day (T+3) in the plots treated with 1000 ppm sucrose. The insecticide treatment resulted in a sharp decrease in thrips populations until day 3 (T+3). Then, the population increased again to reach the level of the "100 ppm sucrose" modality towards the end of the experiment at T+20

In order to better analyze these data, it appears interesting to evaluate their respective effectiveness (Figure 2) and to compare them statistically.

The chemical modality "insecticide" offered a good efficiency from the first day of treatment. The best efficacy was obtained 3 days after treatment (T+3), with 69.64 % ± 2.69 on Sigoise and 81.72 % ± 3.92 on Chemlal, then this efficacy gradually decreased. On the contrary, the efficacy of the sugar treatments, sucrose 1.10 and 100 ppm, increased with time and the best efficiencies were obtained at the end of the experiment at T+20, with respectively 38.39 % ± 1.36, 40.46 % ± 1.72, 48.30 % ± 1.16 on Sigoise and 33.14 % ± 1.39, 41.56 % ± 1.26, 52.48 % ± 1.68 on Chemlal.

Derridj (2009) and Derridj et al. (2011) reported that foliar spraying of sugars at infra doses (in the range of 1 to 10 g 100^{-1}l) on fruit and vegetable plants induces systemic resistances against different pests. These resistances occur on the surface and in the leaves as well as in the roots, against insects, fungal pathogens and nematodes respectively. Indeed, soluble sugars deposited on the plant surface penetrate the plant and can constitute signals that trigger defence cascades within the plant and/or intervene in the plant's physiological regulation pathways. The same authors added that depending on the plant and the pest, the induction of resistance may vary depending on the sugar and its dose. They showed that only sucrose at 10 ppm, fructose at 0.1 ppm sprayed on maize grown under glass had a significant effect on *Ostrinia nubilalis* oviposition, and that the sugar that can induce systemic resistance in tomato to the nematode *Meloidogyne javanica* is sucrose at a concentration of 1 ppm. This dose effect was also observed on *Botrytis cinerea* where the use of 100 ppm sucrose was very effective on tomato against *Botrytis* (100 % reduction of symptoms) and much less on bean (only 23 %). On their side, Arnault et al. (2015) demonstrated that spraying sucrose or fructose at a concentration of 100 ppm was able to reduce codling moth *Cydia pomonella* damage by 55 % in apple orchards.

In our study, after 20 days, the 100 ppm sucrose treatment appeared to be more effective than the treatments at other doses, its efficacy was 48.30 % ± 1.16 on Sigoise and 52.48 % ± 1.68 on Chemlal, and it was even as effective as the treatment with the chemical modality (Figure 2). On the other hand, the least effective treatment, on the two cultivars studied, was the 1000 ppm sucrose, with an efficacy that did not exceed 18 %. Increasing the sugar dose does not increase the effects of

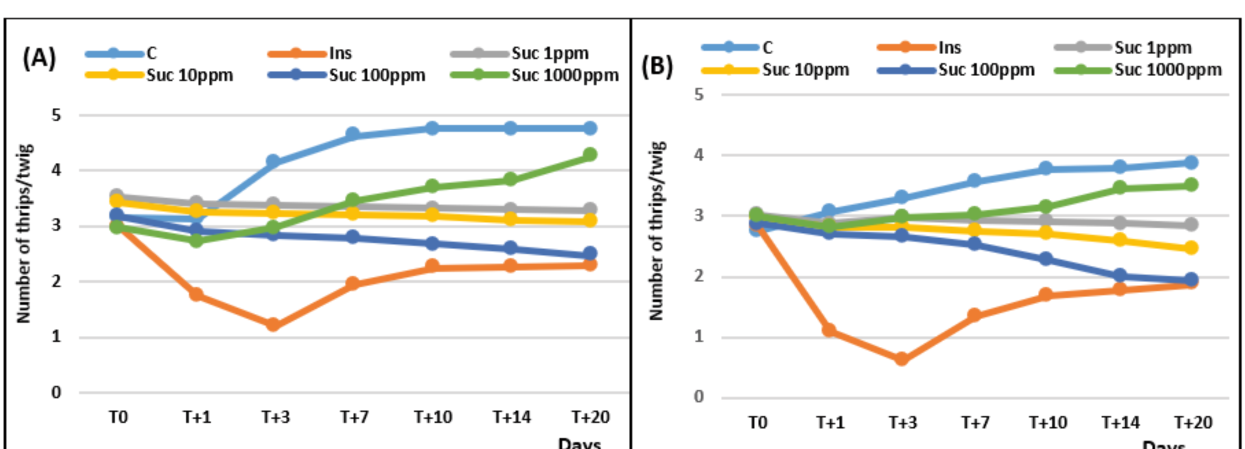

Figure 1: Temporal evolution of the number of thrips per twig according to the different treatments, on the cultivar Sigoise (A) and Chemlal (B) in an olive grove located in the Batna region, in 2017. C (control); Ins= Insecticide; Suc1 = sucrose at 1 ppm; Suc10 = sucrose at 10 ppm; Suc100 = sucrose at 100 ppm; Suc1000 = sucrose at 1000 ppm

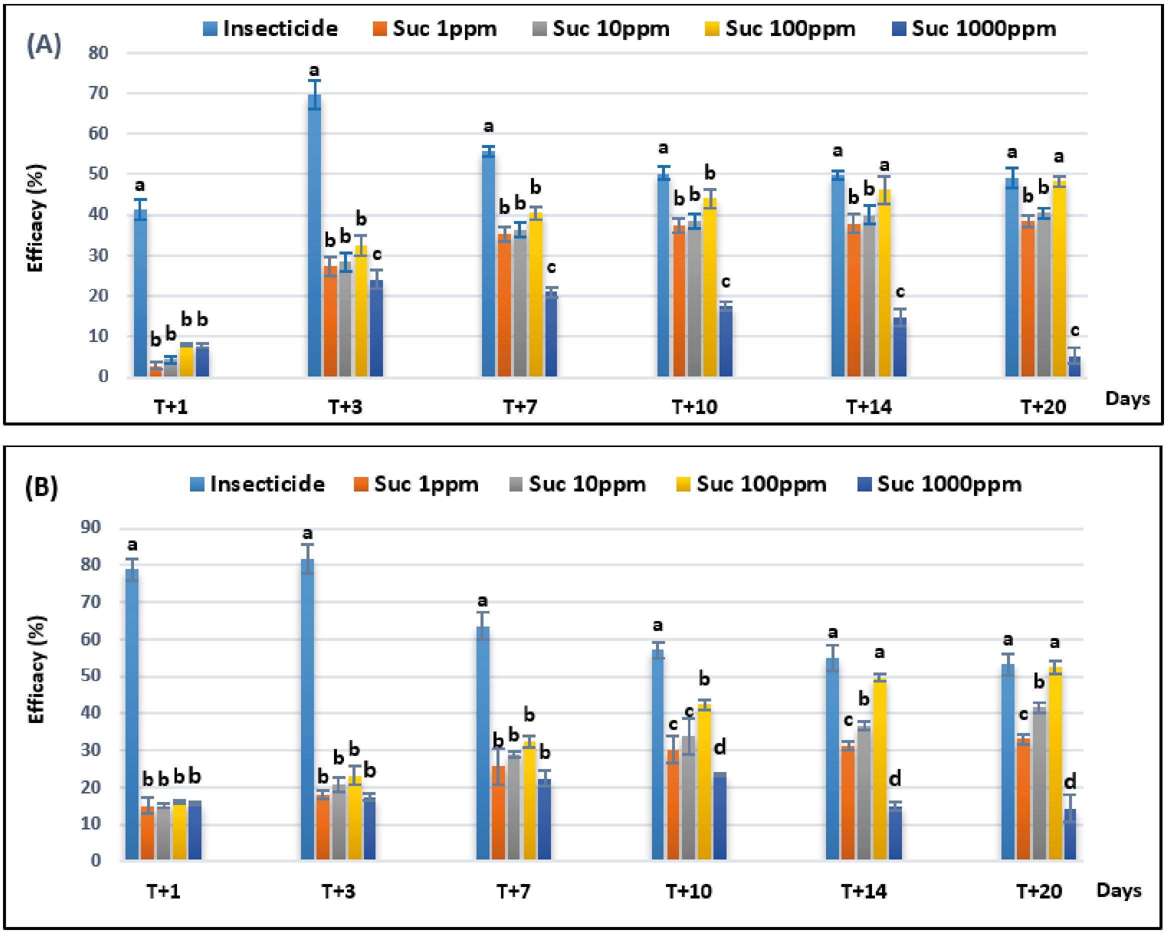

Figure 2: Treatment efficacy, calculated according to the Henderson and Tilton method, at 1, 3, 7, 10, 14 and 20 days after treatment, for the cultivar Sigoise (A) and Chemlal (B), in an olive grove located in the Batna region in 2017. Values with different letters are significantly different (p < 005; Tukey test)

resistance induction and sometimes even cancels them out, and has the disadvantage of having secondary effects (insect feeding, growth and development of epiphytic fungi or bacteria, etc.) on pests on the plant surface (Derridj et al., 2010).

3.3 EFFECT OF THE SUGAR TYPE

The results obtained from the trials conducted in 2018 (Figure 3), showed that treatments with different types of sugar (sucrose, fructose or glucose) and chemical modality resulted in a significant decrease in thrips populations from the first day of treatment. The population levels of the different treated modalities remained significantly lower than the control throughout the experiment.

The results obtained 20 days after treatment (Figure 4) showed that 100 ppm sugar (glucose, fructose or sucrose) sprays on the cultivar Sigoise resulted in a significant reduction of the thrips population compared to the untreated control (2.6 ± 0.78, 3.18 ± 0.67, 2.1 ± 0.78 vs. 4.9 ± 1.16 respectively). On 'Chemlal', glucose, fructose or sucrose treatments at a dose of 100 ppm also resulted in a significant reduction of the thrips population, with a number of 1.4 ± 0.6, 2.13 ± 0.33 and 1.23 ± 0.44 respectively, compared to the untreated control (3.68 ± 0.78)

As reported in the literature, the application of very low doses of sugar to the surface of plants could limit pest attacks by two mechanisms; by modifying the chemical composition of the leaf surface, sugars would disrupt the oviposition behaviour of females, which would not recognize the plant as suitable for the development of their larvae, but also by a systemic effect. Sugars are indeed involved in a cascade of plant defence reactions and can therefore have a generalized effect of stimulating natural defences (Derridj et al., 2011; Arnault et al., 2015; Lambion et al., 2016). Soluble carbohydrates not only act as

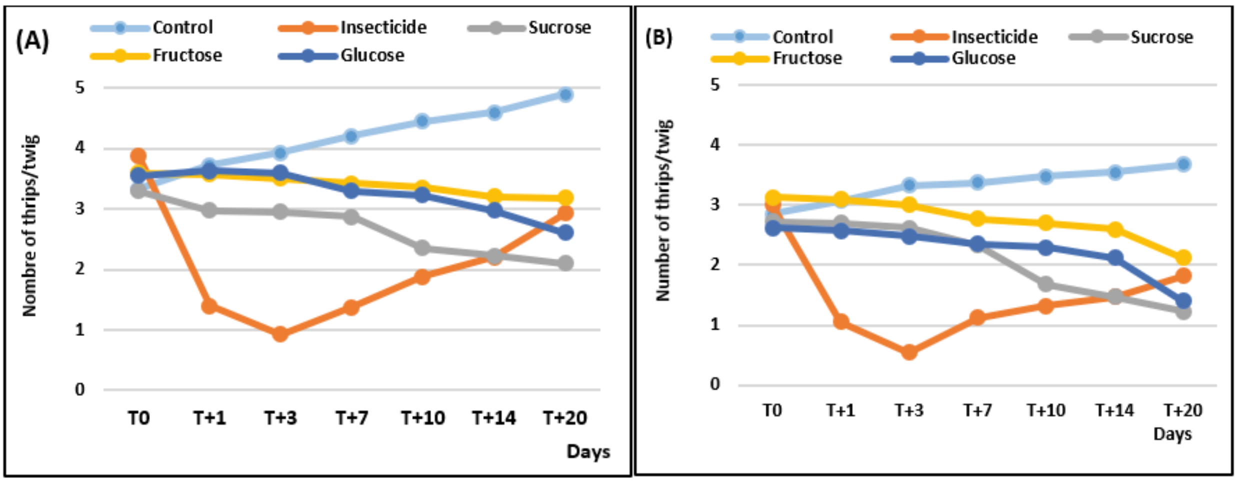

Figure 3: Temporal evolution of the number of thrips per twig according to the different treatments, on the cultivar Sigoise (A) and Chemlal (B) in an olive grove located in the Batna region in 2018

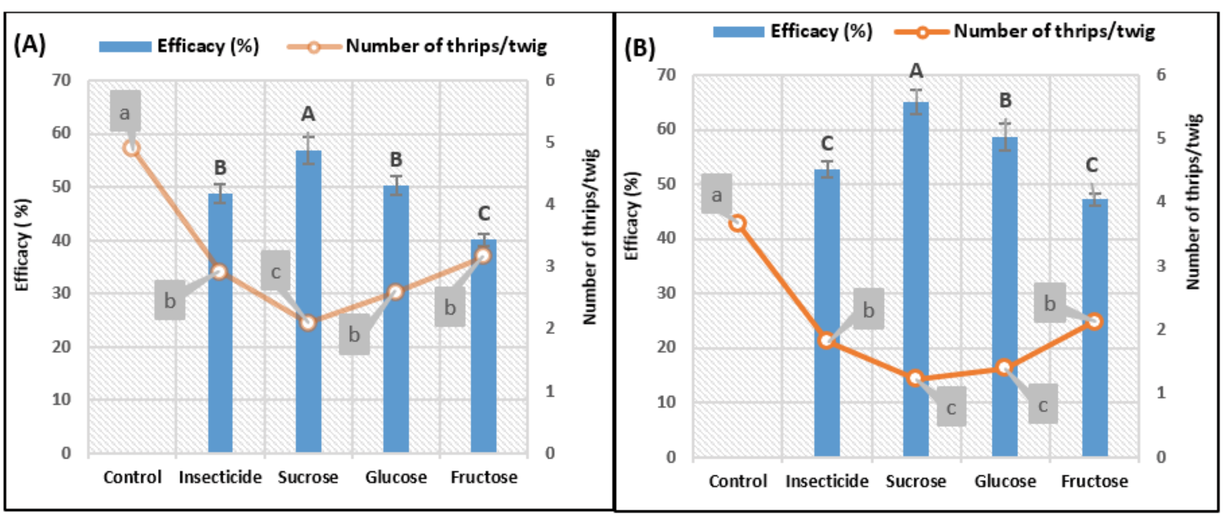

Figure 4: Number of thrips/twig and treatment efficiency, calculated according to the Henderson and Tilton method, at 20 days after treatments, for the cultivar Sigoise (A) and Chemlal (B), in an olive grove located in the Batna region in 2018. The values with the different letters are significantly different [different lower-case letters indicate significantly different mean thrips/twig numbers and different upper-case letters indicate significantly different percentage efficacy ($p < 0.05$; Tukey test)]

carbon skeleton donors and respiratory substrates, but they can also induce metabolic signals influencing the expression of many genes involved in plant defence (Rolland et al., 2006; Morkunas & Ratajczak, 2014; Yoon et al., 2021; Choudhary et al., 2022)

The results acquired from the trials, conducted in 2018 (Figure 4), revealed that the sucrose treatment at 100 ppm offers a more effective protection against thrips (the efficacy is 56.82 % ± 2.55 on 'Sigoise' and 65.14 % ± 2.22 on 'Chemlal'), compared to the treatments with the chemical modality and the other two sugars (glucose or fructose). Indeed, sucrose is the main product of photosynthesis and the main transport carbohydrate in plants (Xu et al., 2018; Aluko et al., 2021). It has been recognized as contributing to various regulatory mechanisms in plants, including growth and development, differential gene expression and stress-related responses (Formela-Luboińska, 2020; Li et al., 2020; Jeandet et al., 2022). High sucrose: hexose ratios can probably trigger a sucrose-specific signal to induce the genes required for the production of a range of protective agents such as anthocyanins and other secondary metabolites (Yoon et al., 2020). The specificity of sucrose as a signalling molecule was demonstrated by the fact that equimolar applications of glucose and fructose did not result in significant accumulation of anthocyanins (Solfanelli et al., 2006).

On the other hand, the 100 ppm glucose treatment was found to be satisfactorily effective for both cultivars tested, with 50.30 % ± 1.70 for 'Sigoise' and 58.64 % ± 2.48 for 'Chemlal'. While fructose at 100 ppm is the least effective sugar, where the efficiency is significantly low compared to the other sugars, which did not exceed 40 % on 'Sigoise' and 47 % on 'Chemlal'. It has been shown that sucrose, glucose and mannitol are the most abundant sugars in olive tree, while fructose is the least present (Bousaadia et al., 2010; Haouari, 2013; DePascali et al., 2022).

Our results are in agreement with those obtained by Valette (2007), who showed that sucrose is the most effective of the three tested sugars (sucrose, glucose and fructose), against thrips on nectarine. Numerous studies have also shown significant protective effects of sucrose at a dose of 100 ppm on different pests such as melon borer and powdery mildew, leek thrips, codling moth, corn borer, tomato leafminer (Derridj, 2009; Derridj et al., 2011, 2012; Arnault et al., 2012, 2015, 2017, 2021)

3.4 EFFECT OF COMBINING SUGAR WITH A PHYTOSANITARY TREATMENT

The obtained results in 2019 trials confirmed the efficacy of sucrose foliar spray, 20 days after treatment (Figure 5), in reducing thrips populations associated with olive. The efficacy was 50.93 % ± 2.52 on 'Sigoise' and 61.83 % ± 2.53 on 'Chemlal'. Sucrose treatment at a concentration of 100 ppm alone induced effects comparable to those recorded with insecticide treatment alone at the recommended dose on the cultivar Sigoise. However, on the cultivar Chemlal, sucrose treatment was more effective than insecticide alone.

Sucrose at 100 ppm improved the efficacy of the chemical modality for both the reference dose (D2) and the halved dose (D1), on both cultivars tested (Figure 5). Indeed, several studies recommend the use of sugars as an additive treatment to phytosanitary treatments. Thus, the work carried out by Derridj et al. (2011), showed that the combination of sucrose at a dose of 100 ppm with a pyrethroid insecticide treatment had a significant effect on the oviposition of the female corn borer *Ostrinia nubilalis*. In plots treated with pyrethroids in combination with 100 ppm sucrose, they observed a 20 % reduction in maize damage compared to maize plots treated with the insecticide alone, where the damage reduction was only 8 %. Similar work by Arnault et al. (2015) also showed that the addition of 100 ppm sucrose to an "organophosphate" chemical treatment increased its effectiveness by 35 %.

Recent experiments (Arnault et al., 2016, 2021; Bouhidel & Lombarkia, 2021), have significantly demonstrated that the addition of sugars, such as sucrose or fructose, can reduce the insecticide dose by up to 50 % while maintaining the same level of efficacy against the pests. This was confirmed by the results obtained in this study, in which the treatment combining 100 ppm sucrose with the insecticide in half dose (D1) was as effective as the sucrose treatment combined with the insecticide in reference dose (D2), on the two cultivars studied,

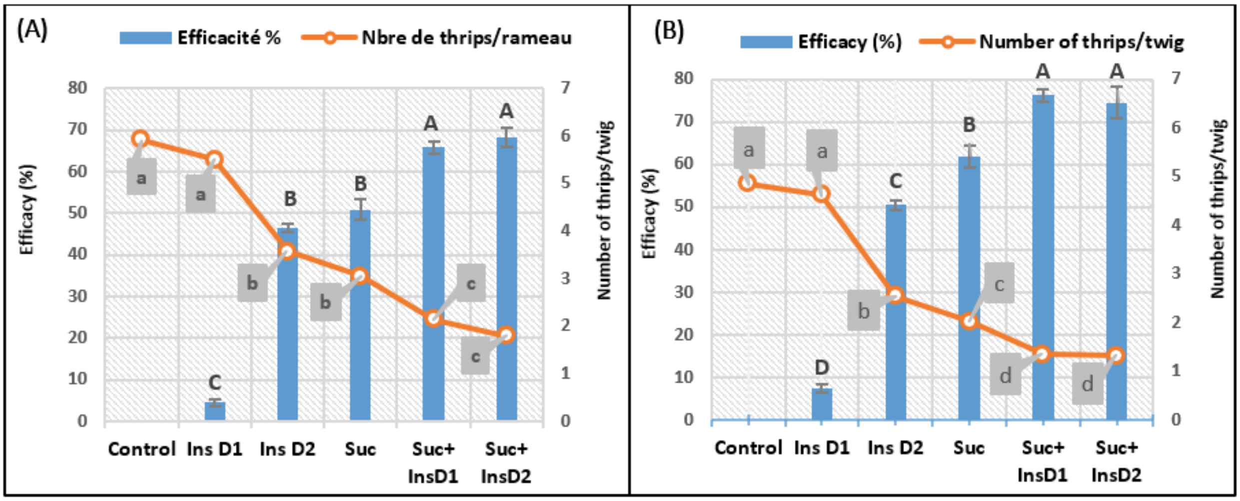

Figure 5: Number of thrips/twig and treatment efficiency, calculated according to the Henderson and Tilton method, 20 days after treatments, for the cultivar Sigoise (A) and Chemlal (B), in an olive grove located in the Batna region in 2019. The values with the different letters are significantly different [different lower-case letters indicate significantly different mean thrips/twig numbers and different upper-case letters indicate significantly different percentage efficacy ($p < 0.05$; Tukey test)]

with an efficacy of 65 to 68 % on 'Sigoise' and 74 to 76 % on 'Chemlal'. The addition of 100 ppm sucrose thus increased the efficacy of a reduced dose of insecticide and resulted in similar efficacy to that obtained with a full dose.

4 CONCLUSION

The conducted trials in the present study showed very promising results. Foliar spraying of sucrose at a dose of 100 ppm showed an improved efficacy on thrips, both alone and in combination with a chemical insecticide. This method reduced the recommended insecticide dose by half while improving the efficacy of the treatment and thus allowing a significant reduction of thrips populations on olive trees.

As a consequence, we can affirm that the use of sugars, which are non-toxic and inexpensive substances, could lower pest population levels to more controllable levels or below economic thresholds, and thus contribute to increase the efficiency of integrated pest management or organic farming methods.

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