Effect of pruning and chemical control on *Saissetia oleae* (Olivier) (Hemiptera, Coccidae) in olives

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Abstract – Introduction. In Morocco the olive growers rely totally on pesticides to control the black scale *Saissetia oleae*, although this technique has adverse effects on natural enemies, on product quality and on the environment. However, the pesticides are not used efficiently because of ignorance of the developmental cycle of the insect, and of the periods of vulnerable instar presence. We studied these two parameters. Next, we tested the efficacy of the pesticide and we studied the effect of pruning on the scales as an alternative to chemicals. **Materials and methods**. The seasonal trend of the black scale was studied in two olive orchards near Essaouira, in the west of Morocco, during 2005 and 2006. One of these orchards was subject to chemical treatment in 2007, while two new orchards were selected to study the effect of pruning on the scales. The evolution of crawler and nymph density on different olive tree organs was followed in order to discover their preferences for these different organs. **Results and discussion**. The seasonal trend study showed the presence of one generation of *S. oleae* per year and the tendency to colonise young organs rather than old ones. The optimum of mobile instar population coincided with the beginning and the end of July. On the organs of the chemically-treated samples, numbers of crawlers and nymphs were highly reduced. The results showed a small-scale infestation in pruned trees compared with the unpruned trees (control). **Conclusion.** Though the chemical control has good results, pruning remains very efficient and can help improve the control of the black scale populations without harming the environment.

Morocco / *Olea europaea* / insect control / *Saissetia oleae* / population dynamics / chemical control / pruning

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Effet de l'élagage et de la lutte chimique sur *Saissetia oleae* (Olivier) (Hemiptera, Coccidae) en vergers d'oliviers.

Résumé – Introduction. Au Maroc, les oléiculteurs comptent entièrement sur les pesticides pour lutter contre la cochenille noire de l'olivier *Saissetia oleae*, bien que cette technique ait des effets nocifs sur ses ennemis naturels, sur la qualité des produits et sur l'environnement. Cependant, les pesticides ne sont pas utilisés de manière efficace du fait de l'ignorance du cycle de développement de l'insecte, ainsi que du moment de présence de ses stades de développement en vergers. Nous nous sommes intéressés à ces deux facteurs. Nous avons testé ensuite l'efficacité d'un pesticide et, pour pallier l'utilisation de produits chimiques, nous avons étudié l'effet de la taille des arbres sur la cochenille. **Matériel et méthodes**. Les variations saisonnières de la cochenille noire ont été étudiées dans deux vergers d'oliviers à proximité d'Essaouira, à l'ouest du Maroc, en 2005 et 2006. L'un de ces vergers a été soumis à un traitement chimique en 2007, tandis que deux nouveaux vergers ont été choisis pour étudier l'effet de l'élagage sur la cochenille. L'évolution des densités de chenilles et de nymphes sur différents organes de l'olivier a été suivie afin d'identifier leurs préférences pour ces différents organes. **Résultats et discussion**. L'étude des tendances saisonnières a montré qu'il se créait une génération de *S. oleae* par an et qu'elle avait tendance à coloniser les organes jeunes plutôt que les anciens. L'optimum de la population de larves mobiles a coïncidé avec le début et la fin de juillet. Dans les échantillons d'organes traités chimiquement, le nombre des chenilles et des nymphes a été fortement réduit. Les résultats ont montré une faible infestation par la cochenille noire dans les arbres élagués par rapport aux arbres non taillés (arbres témoins). **Conclusion**. Bien que la lutte à l'aide de produits chimiques donne de bons résultats, l'élagage demeure très efficace et pourrait contribuer à améliorer le contrôle des populations de cochenilles noires sans nuire à l'environnement.

Maroc / *Olea europaea* / lutte anti-insecte / *Saissetia oleae* / dynamique des populations / lutte chimique / taille

1. Introduction

Saissetia oleae, believed to be native to South Africa [1], is found throughout the tropical and subtropical regions of the world. It is a very polyphagous species with a host range that includes a considerable number of spontaneous and cultivated plants such as oleander *Nerium oleander* L., pepper tree *Schinus molle* L., *Solanum* sp., *Amygdalus* sp., *Citrus* spp. and *Oleae europaea* [2, 3]. In Morocco, the first studies on the bioecology of this insect were carried out in the 1970s [4, 5]. Later, complementary studies concerning other areas of Morocco showed that this species presents one annual generation [6–8]. When the infestations are severe, the losses due to this pest are significant [9] and can exceed 95% in the area of Ouazzane [7], whereas others estimated that the losses vary from 16% to 33% according to the locality and the culture [10]. Black scale is also among the insects to take into consideration when cultivating certified seedlings of olive trees [11, 12]. Unlike a great number of countries in the world [13], Morocco still depends totally on chemicals despite the abundance of the black scale's natural enemies in this country [14].

In France [15, 16], as in Turkey [17] and in California [18], the *Metaphycus* spp. parasitoid shows a significant effectiveness in the control of the black scale populations. In Israel, the use of *Metaphycus* spp., a parasitoid genus of a natural biological control agent in biological control of *S. oleae*, also limits the use of pesticides [19]. This biological control is very beneficial not only regarding the quality of the olive products (olives and olive oil) but also the protection of the environment [20]. However, the use of biological control techniques remains very costly [21]. Hence, other alternative means to control the black scale are needed, one of which is pruning.

Pruning is an important cultural practice which has several positive effects on the olive trees [22]. It can eliminate the infested branches, and consequently can reduce the population of the scale.

In this paper, we will first study the seasonal trend of *S. oleae* on olive trees to determine its emergence peak. Then we will discuss the effects of pruning and of chemical treatment on its populations.

2. Materials and methods

2.1. Seasonal trend of *S. oleae* in young and old orchards

The study of population dynamics of the scale was conducted in the region of Essaouira (Morocco) in two traditional olive groves located in an area of significant rainfall on the road to Safi, 10 km from the coast. Neither of these olive groves received any chemical treatment during the study period. The first orchard of 1 ha was 25 years old, and the second of 5 ha was 10 years old. They were 200 m away from each other. During the years 2005 and 2006, a sample of 40 branches, each 25 cm in length, was taken monthly and examined to determine the population density of the developmental instars (eggs, crawlers, nymphs and female adults) of five randomly selected olive trees. The density was calculated per linear metre.

In the graphic representation of both orchards, the number of eggs was divided by 100, and that of the crawlers and second-instar nymphs was divided by 10, whereas the number of third-instar nymphs and adult females, being small, was left untouched.

2.2. Evolution of crawler and nymph density on different olive organs

In order to discover the model of distribution of the mobile instars of *S. oleae* on different olive organs during 2005 and 2006, a sample of 40 branches, each 25 cm in length, was taken monthly from five randomly selected olive trees belonging to the previously mentioned orchard, and the densities of first-instar and second-instar nymphs were calculated on old and young parts. The density was reported on 400 old leaves (10 leaves × 40 branches) and on 200 young leaves (5 young leaves × 40 branches) and the results were given per leaf. For the young branches (10 cm length), the averages were calculated per linear metre. For the old branches (25 cm length), average numbers were obtained by dividing the crawlers and nymphs found on 40 branches by 1000 cm (40 × 25 cm) to have density by linear metre. This study permitted us to determine: i) the peak period when crawlers and second-instar nymphs reached their highest emergence, and ii) the preferences of these sensitive instars for different olive organs. Our focus on the above-mentioned mobile instars was justified because at these instars, nymphs do not have the impervious shell of the adult females and can be removed by pesticides.

2.3. Effect of pruning olive trees on *S. oleae* populations

Two olive sites in Ounagha and Talmest, 30 km from the Essaouira region, were selected for this study. In the first site, olive trees were pruned in 2004 and 2006, while the second site, whose olive trees were not pruned, was used as a control. Samples of branches were taken during the active period of the black scale (January to August 2007). Five trees were randomly sampled in each site by taking 8 branches from each. Monthly, a sample of 40 branches 25 cm in length per site was examined and the numbers of eggs, nymphs and adult females were recorded. The crawlers (0.4 mm length) were distinguished from the second-instar nymphs (0.8 mm length) by the size and the appearance of the H letter form on the back of the second instars. The data were analysed using a Student t-test with matched samples.

2.4. Effect of chemical treatment on the *S. oleae* population

The treatment was conducted in Talmest, in the same old orchard that was used for the seasonal trend during 2005 and 2006. Once crawlers and second-instar nymphs were completely emerged, a treatment was undertaken in July 2007. Five olive trees were treated with fenthion 50% (Lebaycid, Bayer, France), a standard product, at a dose of 1 $mL \cdot L^{-1}$. Each tree received 10 L of the insecticide. In parallel, five untreated trees, 70 m away from the treated trees, were followed up. After 15 d, a sample of 40 branches was taken from the treated trees and another one from the untreated trees. The numbers of eggs, crawlers and nymphs and living adult females were counted on young and old leaves and branches in each sample to compare the two samples. We used the Abbot formula to determine the efficacy of the product by evaluating the mortality rate: [Mortality = (instar number in the control – instar number in treatment) / instar number in the control].

3. Results and discussion

3.1. Seasonal trend of the scale during 2005 and 2006

3.1.1. In the old orchard

In the old orchard, the eggs started to be laid in May 2005 and they reached their maximum (1480 eggs per linear metre) in the same month. They continued until August (4500 eggs per linear metre) and did not reappear until May of next year (*figure 1*).

The crawlers appeared between May and July or August depending on the year. There was a very high number in 2005 and a lower one in 2006. The second-instar nymphs appeared in all samples except those for January, March, April and May. Their number fluctuated between 54 and 213 per linear metre. The third-instar nymphs were found on branches from September until early April in 2005 and until May in 2006. As for adult females, they appeared from early March to July or August and their densities were relatively lower (2.4–11.3 in 2005 and 0.2–8.9 in 2006). We can note that the duration of different instars was longer in 2006 because the rainfall was abundant and so the humidity was suitable for them.

3.1.2. In the young orchard

In the young orchard, eggs appeared from May to July in 2005 and from April to June in 2006 (*figure 2*). The maximum number of eggs was about 1400 eggs per linear metre

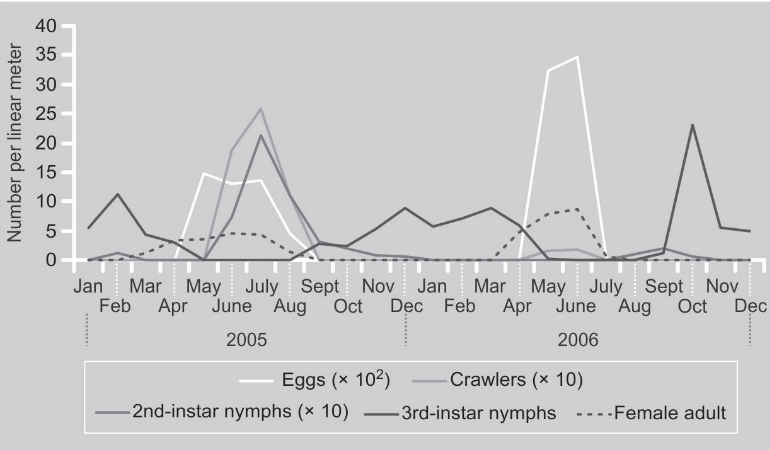

Figure 1.
Seasonal trend of the scale *Saissetia oleae* (Olivier) in an old olive orchard during 2005 and 2006 (Morocco).

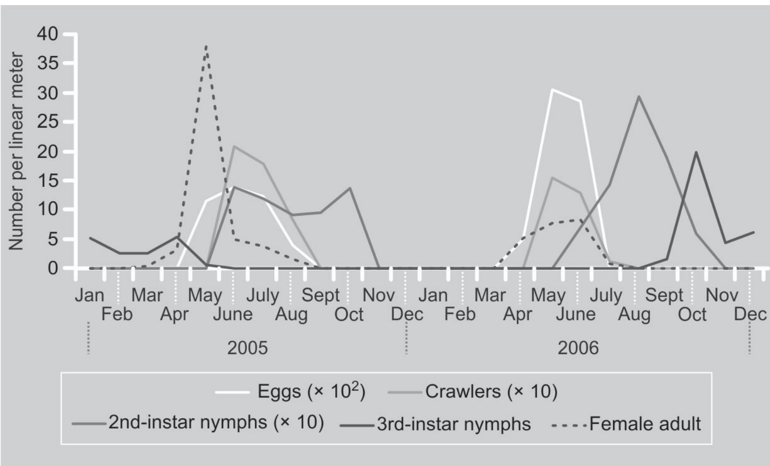

Figure 2.
Seasonal trend of the scale *Saissetia oleae* (Olivier) in a young olive orchard during 2005 and 2006 (Morocco).

in June 2005 and 3070 in May 2006. The crawlers and nymphs followed the same trend as in the previous orchard. Indeed, the crawlers appeared just after hatching and persisted until August 2005 and July 2006. Their numbers reached 208 and 156, respectively, in June 2005 and May 2006. The second-instar nymphs emerged in June and continued until October. The third-instar nymphs, which presented lower numbers, were present in all surveys between September 2005 and May 2006 and from January to March 2005. As in the old orchard, the adult females were found in surveys conducted between March and August with different peaks; 38 adult females per linear metre in May 2005 and 8.4 adult females per linear metre in June 2006.

Moreover, the evolution of developmental instars did not differ significantly from one year to another. For all instars, probability was superior to 0.186. However, for the different instars, a very highly significant difference was noted between months since the cycle of the scale evolves over time. Moreover, the interaction between year and month is not significant.

3.2. Evolution of crawler and nymph density on different olive organs

Crawler and nymph density varied from a minimum of 0.013 per old leaf to 2.8 as a maximum per young leaf in 2005, and from a minimum of 0.014 on old branches (14 per linear metre) to a maximum of 1.65 on young branches (165 per linear metre). The presence of these instars was concentrated between May and August in 2005 and 2006 (*figure 3*).

Statistically, these densities varied significantly from one organ to another ($P < 0.001$). These immature instars showed a preference for the young leaves and branches. This can be attributed to the fact that young tissues are rich in sap and tender, so young crawlers can easily suck the sap. Also, these crawlers remain on the same organ and do not move far away from it [10].

During summer, eggs hatch into tiny, six-legged, cream-coloured 'crawlers'. The crawlers move up to the stems and usually settle along the veins of young leaves. Normally, crawlers will moult after one month and then migrate to the young stems and branches of the tree [4].

The population of the second-instar nymphs was low in 2005 due to mortality caused by the high temperature during this period (between 31 °C and 36 °C on average from June to September), and relatively higher in 2006 because the relative humidity was higher (> 60%) (*figure 4*). The densities were maximum on the young leaves in 2005 (2.6 individuals per leaf, the equivalent of 520 nymphs per linear metre) and on the old leaves in 2006 (5.2 individuals per leaf or 2080 nymphs per linear metre). These results are similar to those of Paparatti, who indicated that, after the second moult, nymphs moved towards the leaves [10]. For others, the second instars typically migrate from the leaves back to the branches [23]. From the results of mobile instar-L1 and -L2 densities, we note that the maximum of crawlers occurred in the last part of June and the maximum of second-instar nymphs was reached in August. Consequently, chemical treatments must target both instars and thus must take place in two phases: a first treatment at the beginning of July to destroy the maximum number of crawlers and a second one a month later in order to reach the maximum number of second-instar nymphs.

In the same way, in Spain, populations peaked in July, when crawlers emerged after the egg-laying period, and decreased in summer due to mortality of crawlers [23–25]. Thus, two pesticide applications are advised. This approach seems largely questionable because of the doubling of the distribution cost.

3.3. Seasonal trend of *S. oleae* under pruning

Comparing the variation in the infestation of branches from pruned and unpruned olive trees (control), it appeared that the level of branches infested by eggs, nymphs and adult females was higher in the control than in all the samples from the pruned trees (*figure 5*). The pruning reduced the number of eggs from 1.6 to 2.3 times; whereas the nymph reduction due to this technique was almost two-fold less. The number of adult females also underwent a reduction of their population by half. The Student t-test used to compare the total numbers of various instars of the scale from the two orchards (pruned and the control) showed that these differences are significant for all the instars: indeed, for eggs, $t = -2.57$ with ($P = 0.021$, degree of freedom = 15); for the nymphs (including crawlers), $t = -2.426$ with

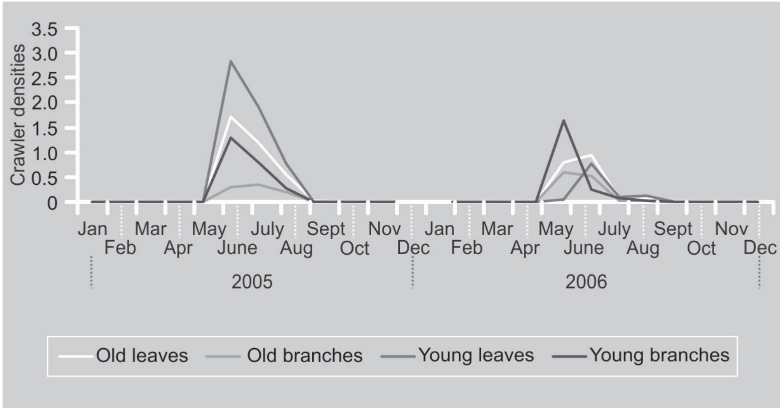

Figure 3.
Density of crawlers of the scale *Saissetia oleae* (Olivier) on old and young leaves per leaf, and on old and young branches per linear metre in two olive orchards during 2005 and 2006 (Morocco).

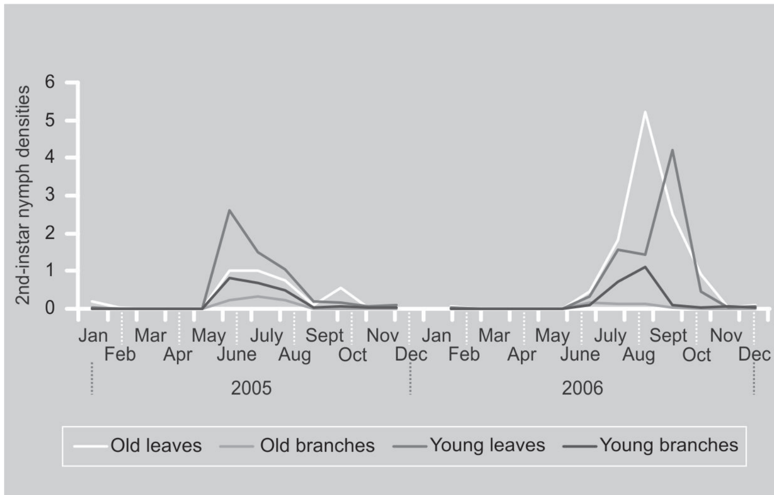

Figure 4.
Density of second-instar nymphs of *Saissetia oleae* (Olivier) on old and young leaves per leaf, and on old and young branches per linear metre in two olive orchards during 2005 and 2006 (Morocco).

($P = 0.028$, degree of freedom = 15); and for adult females, $t = -2{,}919$ with ($P = 0.011$, degree of freedom = 15).

These results show that the level of infestation by the various instars of the scale is lower in the pruned orchard than in the control. These results are in conformity with those found by other authors. On olive trees,

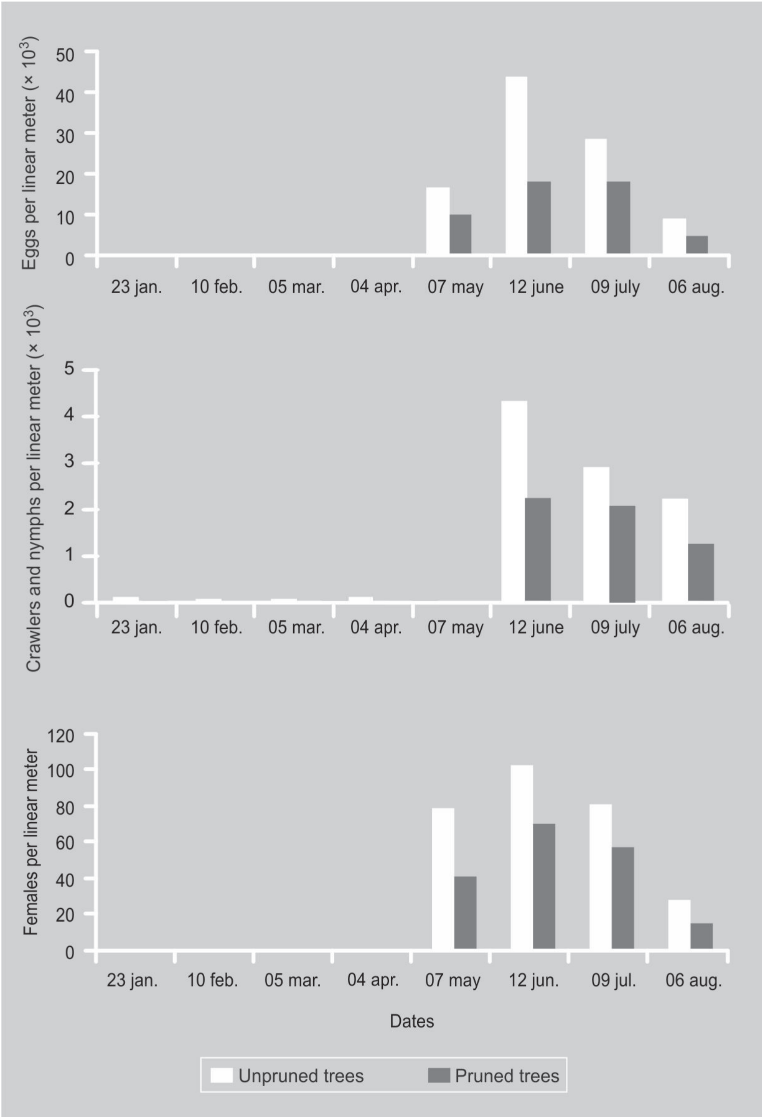

Figure 5.
Evolution of developmental instars of the scale *Saissetia oleae* (Olivier) in a pruned and an unpruned (control) orchard from January to August 2007 (Morocco).

it was also stated that a good pruning can reduce the level of infestation by the black scale [26, 27]. Daane and Caltagirone also reported that the fluctuations of *S. oleae* were influenced by cultural practices such as pruning [23]. This technique, among others, affects temperature and humidity in the olive tree canopy, and, in turn, markedly influences scale development and survival. For other insects, it is claimed that the pruning practice reduces the incidence of the infestations. Saunyama and Knapp reported that, for tomato plants attacked by the acarina *Tetranychus evansi* Baker and Prichard, the rate of infestation was about 34 individuals of acarina per leaf in the control plants, whereas in the cut plants this rate was only about 11 acarina individuals per leaf [28]. Liu *et al.* showed that the effects of cutting varied significantly with the kinds of insect pests on alfalfa [29]. The seasonal average of population densities of *Therioaphis trifolii*, *Acyrthosiphon pisum* and thrips decreased significantly and were maintained at a low level under the cutting regime. Onillon reported that trees with a dense canopy are more susceptible to insect pest attacks [30]. In addition, the pruning technique would significantly reduce the number of pests in *Medicago sativa* (alfalfa) [31]. Chaboussou announced that the physiology of the plant host influences the nutrition, and consequently the dynamics of the populations of insects [32]. Other authors demonstrated that irrigation can be manipulated to suppress insect herbivore density without negatively influencing crop yield vines [33]. Thus, subsequent to the pruning, it would be necessary to provide balanced fertilisers to the trees and to destroy weeds [34]. In the light of these results, cultural control through pruning permits an open and airy tree that discourages black scale infestation. In addition, this technique also allows a better penetration of the pesticide treatments. However, it is necessary to burn the underwood to avoid a new infestation [25].

3.4. Seasonal trend of *S. oleae* under chemical treatment

For the control orchard, the average number of nymphs per linear metre of branch was high. The values ranged from 30.4 nymphs per linear metre on the young branches, 32.8 nymphs on the old branches and 33.6 on the young leaves (*figure 6*). On the old leaves, the average number of nymphs was the highest, with about 44 nymphs per linear metre of branches, which represents a strong infestation that requires a chemical intervention.

After the application of fenthion, a reduction of the populations of nymphs was noted; about 13.4 nymphs per linear metre on the old leaves, 8.8 nymphs on the old branches, 5.2 nymphs on the young leaves and 6.4 nymphs on the young branches. It should be noted that the larval populations were reduced 3.23, 3.70, 6.50 and 4.75 times compared with the control.

The mortality ranged from 70% to 87% on the leaves and from 75% to 85% on the branches (*figure 7*). We also noted that the death rate was higher on young organs compared with the old. The average mortality calculated on all parts of the olive tree in this orchard was about 79%.

Fenthion significantly reduced the *S. oleae* nymph population, which reached up to 87%. The Student *t*-test detected a highly significant difference between the number of nymphs of the first and second instars in the treated orchard and the control with, respectively, $t = -3.587$ ($P = 0.037$, degree of freedom = 3) and $t = -5.564$ ($P = 0.011$, degree of freedom = 3) for the first and second instars. In addition, the complete inefficiency of fenthion is explained by the spreading out of the hatching in time, which makes the application of only one treatment insufficient. Considering the variation in the density of the first and second instars (*figures 1*, *2*), subject to the chemical interventions, we recommend a first treatment during the first week of July, and a second treatment after one month in order to reach the maximum of hatched crawlers. In California, pesticides are usually applied in July and August against the first and second instars, which are more susceptible to insecticides [23].

Infestations of live mature scale may need spraying with an insecticide such as Supracide or Lebaycid. Californian olive growers use oil emulsions, diazinon 50WP, methidathion and carbaryl. Greek olive growers use Supracide as an all-rounder for many olive problems. Nevertheless, resistance of this pest to several chemicals has been reported in some countries [35].

Concurrently with the fenthion used for this study, several insecticides are usually used in Moroccan olive-growing orchards to control *S. oleae*, in particular: methomyl, lamda cyalothrine, dimethoate, parathion, malathion and cypermethrine. However, these products present a lethal effect on the adults of the *Pullus mediterraneus* parasitoid which constitutes an important predator of *S. oleae* eggs [13]. In Morocco, methidaxide 40 and Ultracide 40 EC (methidathion), Promazit blanche (mineral oil) and Sevin 85 WP (carbaryl) are also certified on the black scale on olives [36].

In conclusion, agricultural practices such as pruning associated with a well-applied treatment constitute an important tool to improve the health status of olives, so their involvement in the integrated control of olive groves will be more than appreciated. In addition, monitoring of scale populations

Figure 6.
Average of crawlers (L1-instars) and nymphs (L2-instars) per linear metre [*Saissetia oleae* (Olivier)] in treated and untreated (control) branches and leaves of olive trees. Samplings were taken 15 d after a treatment with fenthion 50% (Lebaycid, Bayer, France) undertaken in July 2007 (numbers should be multiplied by 100).

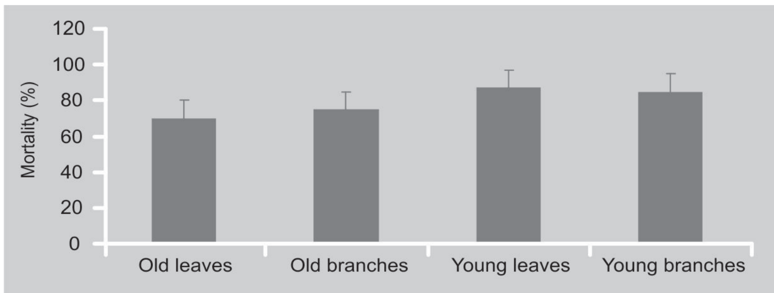

Figure 7.
Mortality rate calculated with the Abbot formula from samplings in treated and untreated (control) branches and leaves of olive trees. Samplings were taken 15 d after a treatment with fenthion 50% (Lebaycid, Bayer, France) undertaken in July 2007.

is recommended to help in timing cultural or chemical control measures. A sampling programme with control thresholds should be developed for olive growers in Morocco.

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El efecto del aclareo y de la lucha química en *Saissetia oleae* (olivier) (Hemiptera, Coccidae) en vergeles de olivos.

Resumen – Introducción. En Marruecos, los oleicultores cuentan totalmente con los pesticidas para luchar contra la cochinilla negra del olivo *Saissetia oleae*, a pesar de que esta técnica tenga efectos nocivos en sus enemigos naturales, en la calidad del producto y en el medioambiente. Sin embargo, los pesticidas no se emplean eficazmente, porque se ignora el ciclo de desarrollo del insecto, al igual que el momento de presencia de sus fases de desarrollo en vergeles. Nos interesamos en estos dos factores. A continuación, sometimos a prueba la eficacia de un pesticida y, para paliar el uso de productos químicos, estudiamos el efecto de la tala de los árboles en la cochinilla. **Material y métodos**. Las variaciones estacionales de la cochinilla negra se estudiaron en dos vergeles de olivos cercanos a Essaouira, al oeste de Marruecos, en 2005 y 2006. Uno de esos vergeles fue sometido a un tratamiento químico en 2007, mientras que dos nuevos vergeles se eligieron para estudiar el efecto del aclareo en la cochinilla. Se hizo un seguimiento de la evolución de las densidades de las orugas y de las ninfas en diferentes órganos del olivo, con el fin de identificar sus preferencias por estos órganos diferentes. **Resultados y discusión**. El estudio de las tendencias estacionales mostró que se creaba una generación de *S. oleae* al año y que tenía tendencia a colonizar los órganos jóvenes más que los ancianos. El punto óptimo de la población de larvas móviles coincidió con el principio y el final de julio. En las muestras de órganos tratados químicamente, el número de orugas y de ninfas se redujo fuertemente. Los resultados mostraron una infestación floja de la cochinilla negra en los árboles escamonandos en relación con los árboles sin podar (árboles testigo). **Conclusión**. A pesar de que la lucha con ayuda de productos químicos ofrezca buenos resultados, el aclareo sigue siendo muy eficaz y podría contribuir a mejorar el control de las poblaciones de cochinillas negras sin perjudicar al medioambiente.

Marruecos / *Olea europaea* / control de insectos / *Saissetia oleae* / dinámica de poblaciones / control químico / poda