Study of the control methods practiced against the Mediterranean fruit fly (*Ceratitis capitata* Wiedemann, 1824) in citrus orchards of the Moulouya region

Khfif Khalid [(1)], Benyazid Jamal [(2)], Bouharroud Rachid [(3)], Mokrini Fouad [(4)] and Sbaghi Mohamed [(5)]

khalid.khfif@inra.ma

1: Research Unit on Nuclear Techniques, Environment, and Quality, National Institute for Agricultural Research (INRA), 78 Bd. Sidi Med. Ben Abdellah, 90010 Tangier, Morocco.
2: Laboratory of Biochemistry and Biotechnologies, Mohamed First University, Faculty of Sciences, Oujda, Morocco.
3: Integrated Crop Production Unit, National Institute for Agricultural Research, Inezgane, Agadir, Morocco.
4: Biotechnology Unit, National Institute for Agricultural Research, Rabat, Morocco
5: Plant Protection Department, Scientific Division, National Institute for Agricultural Research, Rabat, Morocco.

Abstract

The Mediterranean fruit fly (*Ceratitis capitata*) is the most devastating insect on citrus in the irrigated area of Moulouya, Morocco, which is known by the production of many citrus varieties, e.g., Berkane Clementine and Navel. Monitoring and control practices of fruit fly in over 40 farms producing and exporting citrus in the province of Berkane were investigated in a survey conducted in 2016. The results showed that 53% of sampled farms were supervised by the private sector which provides monthly monitoring of the insect. The survey showed that one to two pheromone traps per hectare were placed in a zigzag pattern in the orchard. Farmers used chemical treatments when an average daily threshold of 4 flies per trap was reached, regardless of the sex captured. Half of the farmers (51%) employed mass trapping by pheromone traps, e.g., Ceratrap®, with an average density of 30 traps per hectare. The technique of straw plug is used by 62% of the farmers interviewed with an average density of 82 straw plugs per hectare. The chemical treatment is the most common control method used by the surveyed farmers, and only 17% of them are opting for a localized treatment. The results obtained allow us to reveal the current state of the fruit fly control and the challenges facing farmers who export fruit to the Russian market. These data will be used to highlight the advantages and disadvantages of continuing some approaches held actually and initiate future research programs of integrated management against the Mediterranean fruit fly.

Key words: citrus, *Ceratitis capitata*, pheromone traps, chemical treatment, mass trapping, straw plug.

Etude des pratiques de lutte menées contre la mouche méditerranéenne des fruits (*Ceratitis capitata* Wiedemann, 1824) en vergers d'agrumes dans la région de Moulouya

Résumé

La mouche méditerranéenne des fruits (*Ceratitis capitata*) est considérée comme l'insecte le plus redoutable sur agrumes dans le périmètre irrigué de Moulouya qui est connu principalement par la production d'agrumes notamment la variété de Clémentine de Berkane et Navel. Les résultats de nos investigations durant 2016 auprès de 40 producteurs et exportateurs d'agrumes dans la province de Berkane ont montré que la moitié (53%) des agrumiculteurs sont encadrés par le secteur privé, assurant des visites mensuelles des vergers suivis. Une densité d'un à deux pièges à phéromone est adoptée par les producteurs enquêtés. Les résultats obtenus montrent que 37% de ces agriculteurs distribuent les pièges selon un zigzag au niveau du verger, les surveillent chaque jour et que le seuil d'intervention est en moyenne de 4 mouches par piège par jour, indépendamment du sexe capturé. La moitié des agriculteurs (51%) emploie le piégeage de masse par phéromone, moyennant le piège Ceratrap® avec une densité moyenne de 30 pièges par hectare. La technique des bouchons de paille est employée par 62% des producteurs avec une densité moyenne de 82 pièges à l'hectare. Les traitements chimiques généralisés contre la mouche est la technique de lutte la plus employée par ces agriculteurs, dont 17% uniquement optent pour un traitement localisé. Ces résultats seront exploités pour ressortir les atouts et les inconvénients des approches poursuivies et ainsi initier un programme de recherche futur sur la gestion phytosanitaire de la cératite.

Mots clés : agrumes, *Ceratitis capitata*, pièges à phéromone, traitement chimique, piégeage de masse, bouchons de paille.

دراسة طرق المكافحة المتبعة ضد ذبابة فاكهة البحر الأبيض المتوسط (*Ceratitis capitata* Wiedemann, 1824) في بساتين الحمضيات بمنطقة ملوية

خالد الخفيف، جمال بن يزيد، رشيد بوهرود، فؤاد مقريني ومحمد السباغي

ملخص

تعتبر ذبابة فواكه البحر الأبيض المتوسط، والمعروفة ب (*Ceratitis capitata*) ، الحشرة الأكثر شراسة على الحوامض في المنطقة المسقية لملوية والمعروفة بإنتاج الحوامض بشكل رئيسي وخاصة نوعي Clémentine de Berkane و Navel . وتشير نتائج البحث لدينا لسنة 2016 عن 40 منتجي ومصدري الحوامض في مقاطعة بركان أن 53٪ من هؤلاء المزارعين مؤطرين من قبل مهنيي القطاع الخاص، بمتوسط زيارة ميدانية شهريا. وكانت كثافة 1 أو 2 من الفخاخ للهكتارالواحد في المتوسط الأكثر استعمالا بالنسبة للمنتجين المستجوبين لمراقبة الذبابة, في حين 51 ٪ من الفلاحين المستجوبين يستخدمون المحاصرة الشاملة باستعمال فخ CERATRAP® مع كثافة متوسطة تمثل ب 30 فخ للهكتار الواحد, كما يتم استخدام تقنية لفافات القش بنسبة 62٪ من هؤلاء المنتجين باستعمال 82 فخ للهكتار الواحد ككثافة متوسطة. وأظهرت النتائج أن 37٪ من هؤلاء المزارعين يوزعون الفخاخ في خط متعرج في الحقل وعتبة العلاج الكيميائي لهؤلاء المزارعين بلغ متوسط 4 ذبابات في الفخ الواحد يوميا، بغض النظر عن جنس الذبابة المقبوض عليها. العلاجات الكيميائية المعممة ضد هذه الذبابة هي تقنية التحكم الأكثر استخداما على نطاق واسع من قبل المزارعين، فقط 17٪ منهم يختارون العلاج الموضعي. هذه النتائج ستمكننا من معرفة الحالة الراهنة لمحاربة ذبابة الفاكهة المتوسطية في هذه هذه النتائج لتسليط المنطقة من طرف المنتجين و المصدرين إلى السوق الروسية. وسوف تستخدم الضوء على مزايا وعيوب طرق الوقاية المستخدمة حاليا والشروع في برنامج دراسات مستقبلية للوقاية من ذبابة فاكهة البحر الأبيض المتوسط الضارة بالحمضيات.

الكلمات المفتاحية : حوامض، آفات ،*Ceratitis capitata* ، فخاخ، المعالجة الكيميائية، المحاصرة الشاملة بالمصائد، لفافات القش.

Introduction

The citrus sector plays a crucial socio-economic role in Morocco. This sector represents a source of revenue to numerous families by providing local employment opportunities, thus ensuring the supply and maintaining a major packaging and processing industry. According to ORMVAM (2017), the citrus sector is the most dominant in the irrigated area of Moulouya, counting about 17% of the national production. In 2019, the citrus area in this region was estimated at 21518 ha (Maroc Citrus, 2020). In 2017, this area was 19800 ha with an average clementine production of 170,000 tonnes and a yield of 16.3 t/ha. For the Navel variety, 108,000 tonnes were recorded with a yield of 22 t/ha (ORMVAM, 2017). However, citrus fruits are attacked by many pests which cause significant damage to production, namely ceratitis, mites, cochineals, aphids, and leafminers on young citrus plantations, in addition to fungal and viral diseases (Abbassi, 2010). However, the Mediterranean fruit fly, also known as ceratitis or medfly (*Ceratitis capitata* Wiedemann, 1824) (Diptera: Tephritidae), remains the most devastating insect on citrus fruits and it exists in all citrus-growing areas in Morocco. The fruit damage caused by the medfly consists of egg-laying bites of the females and galleries generated by the larvae, which constitute a pathway for the penetration of micro-organisms, responsible for the decomposition and premature drop of the fruits. According to MAPM (2018), citrus exports in 2018 were 677000 tonnes and reached a record of 715459 tonnes in 2019 (Maroc Citrus, 2020). These exports are intended mainly for the Russian and American markets and can reach a higher amount if we properly succeed to manage the problem of ceratitis, which is an endemic pest in Morocco and a quarantine insect for several countries including the United States of America. In 2016, larvae detection on Moroccan clementines at the port of Philadelphia (USA), had resulted in a temporary suspension of all Moroccan citrus exports (Lyoussi, 2016). Hence, the primary goal of the present work was to evaluate the control techniques practiced against *C. capitata* to set up an integrated management program, for a quantitative and qualitative improvement of the citrus production in the Oriental region and to extend it nationally. The methodology used in this study was based on two main axes: i) collection and establishing a database from ORMVAM and ONSSA in Berkane and ii) conducting a survey among selected farmers. The actions targeted by this methodology can be classified as follows: 1) to evaluate the adherence of farmers in the Moulouya irrigated perimeter to control techniques against ceratitis on citrus fruits, and 2) to evaluate the advantages and disadvantages of the practicability of these techniques in the field. The actions carried out in this study will improve our understanding of the control strategies used by farmers against ceratitis in the province of Berkane. This will clarify possibilities to improve and strengthen the existing trapping system and employ new management tools against medfly.

Materials and methods

Field study and database

The study was carried out in 2016 in the irrigated perimeter of Moulouya (Oriental), which is located in the northeast of Morocco. The region is characterized by a semi-arid Mediterranean climate and is cultivated mainly by citrus fruits (*Berkane's Clementine* and *Navel*). The overall objective of the study was to evaluate the control techniques put in place by ONSSA, within the framework of the Moroccan-Russian phytosanitary agreement for the reinforcement of the fight against the Mediterranean fruit fly (*Ceratitis capitata*) on citrus fruits intended for export to the Russian market in the irrigated perimeter of Moulouya. To achieve this objective, a series of visits took place at ORMVAM and ONSSA in Berkane to make an inventory of the citrus sector in the Oriental region, such as the yield and the area of citrus fruits (young plantations and productive fields), the varietal spectrum used and its importance according to the subdivisions in the irrigated perimeter of Moulouya.

Our approach was dedicated primarily to the exporters concerned with the Russian market. Indeed, these farmers are required to apply control techniques demanded by the international market and controlled by ONSSA. A list of cooperatives and packaging stations exporting mainly to Russia and also to Europe located in the province of Berkane was provided by the Plant Protection Service of ONSSA in Berkane. We visited six cooperatives, having each a membership list of about 30 members. Six citrus farmers were randomly sampled from these lists. Therefore, 20% of citrus farmers exporting to Russia were surveyed, in addition to six farmers who have packaging stations.

Work method and sampling

The survey developed allowed us to collect general data about the farm: GPS coordinates, area, varieties cultivated, planting date and production yield. Then, we conducted a questionnaire with key questions on applied control of ceratitis. Initially, questions focused on surveys, mass trapping, use of pesticides and non-chemical practices. Additional data about secondary phytosanitary problems, the control methods adopted, constraints encountered and expected solutions allowed us to have an idea of the current phytosanitary state of this citrus sector. The location of the farms visited on the map was constructed using ArcGIS software based on the GPS coordinates collected (GPSMAP 60CSx, Garmin, France). In addition, we collected pest samples causing significant damage to citrus for the subsequent determination and identification. Laboratory identification was performed using a microscope WF 10X22 (CETI, United Kingdom) equipped with a camera 1X (Jenoptik, Progres CapturePro, Germany).

Data statistical analysis

The data were analyzed using Excel (Version 2010). The analysis of variance and correlation was done by SPSS (Version 20), and the processing of GPS was coordinated by ArcGIS (Version 10.2.2).

Results and discussion

General information about the sampled areas

Forty producers and exporters of citrus fruits were surveyed in the province of Berkane with the two subdivisions according to the distribution of ORMVAM: a subdivision of Madagh (CMV 101, CMV 106 and CMV 108) and another of Boughriba (CMV 102, CMV 104 and CMV 105). The location of citrus farms concerned by our study is demonstrated on the geographical map in Figure 1 according to its GPS coordinates.

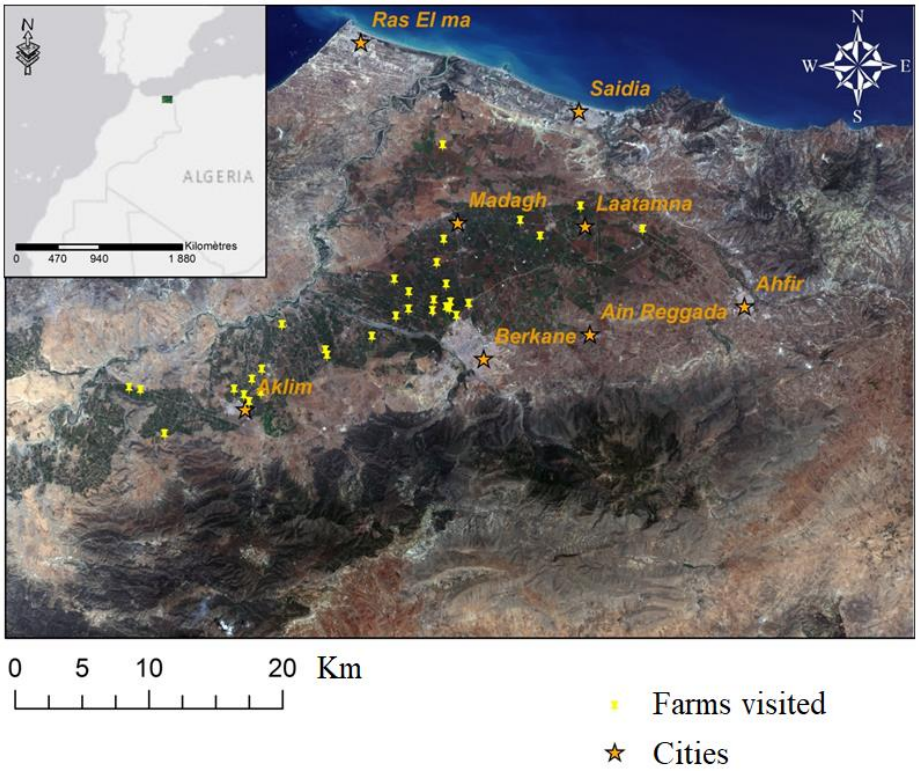

Figure 1. Location of the citrus farms studied

According to this study, 61% of the producers surveyed have less than 10 ha, 22% have between 10 and 100 ha and 17% of farmers have orchards exceeding 100 ha. The main cultivated variety is Berkane's Clementine which was common among all the farms visited. There are other cultivars: Navel (within 38% of the farmers), Nour (17%), Nules (7%) and Maroc-late (5%) (Figure 2). Their average yield is 30 tonnes per hectare with a maximum of 55 t/ha and a minimum of 15 t / ha. Regarding the age of the trees, 60% of citrus growers have 46-years-old orchards and 40% have 22-years-old trees. Thirty percent of farmers have young plantations less than 5 years old.

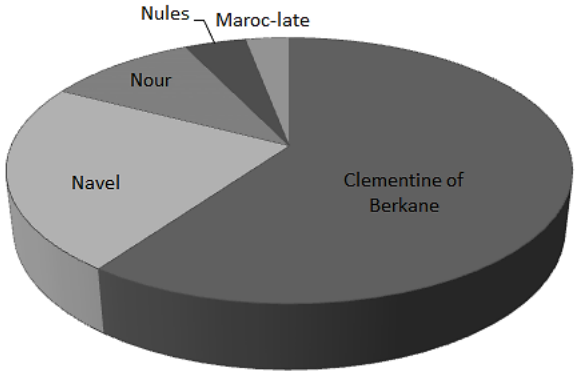

Figure 2. Citrus varieties cultivated by surveyed farmers

Supervision state

Small producers (areas less than 10 ha) in the region are supervised, and guided by large producers within an aggregation framework, which is one of the Green Morocco Plan foundations. KANTARI Group is one of the largest citrus fruit producers in the Oriental region of Morocco and it provides support to the small producers within the collaboration. Our results revealed 3 groups of farmers, demonstrated in Figure 3: those who are supervised by the KANTARI (28% of all the participants interviewed), suppliers of chemical inputs (25%) and farmers out of this collaboration (47%). The average supervision frequency consists of one site visit per month. The rest of the producers do not receive any supervision and they manage the phytosanitary protection of their orchard by themselves based on their experience. This group is represented mainly by professional technicians or simple farmers.

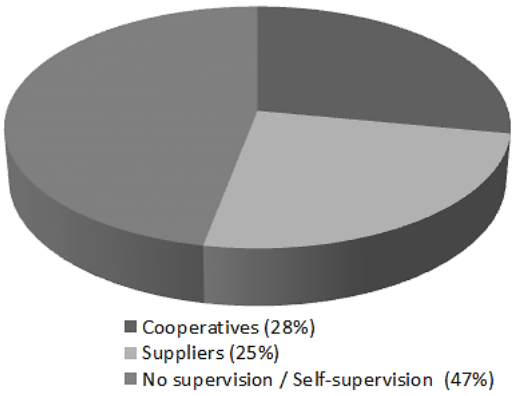

Figure 3. Rate of supervised farmers

More than half of farmers (56%) are aware of the ONSSA action program against ceratitis, which is intended for the producers-exporters to the Russian market. However, 43% remain unaware of this program due to the lack of supervision by state establishments.

Monitoring of the citrus medfly

Monitoring remains an essential tool for predicting medfly attacks and for the proper chemical control while respecting the intervention threshold. The use of pheromone traps is widely practiced by the producers surveyed with an average density of 1 or 2 traps per hectare. It can go up to 4 traps per hectare or even the absence of monitoring traps when farmers use only visual observations to detect the fly presence or possible fruit bites. The ideal monitoring is to observe 5 fruits per tree. The presence of a fly bite indicates the fruit infestation (Chouibani et al., 2016). All farmers have been aware of the importance of fly monitoring. They monitor the traps every day once they are installed until the end of August or the beginning of September. These traps are set at a height of one and a half meters on the sunny side of the tree (south-east face). Figure 4 shows that 37% of these farmers distribute the traps in a zigzag way in the orchard. Among the others, 29% distribute them on the field edges to get an idea of the time of the first medfly intrusions. Ten percent of farmers place traps in the middle and 19% install them in both, the middle and the borders. The rest of the farmers (5%) maintain a random distribution.

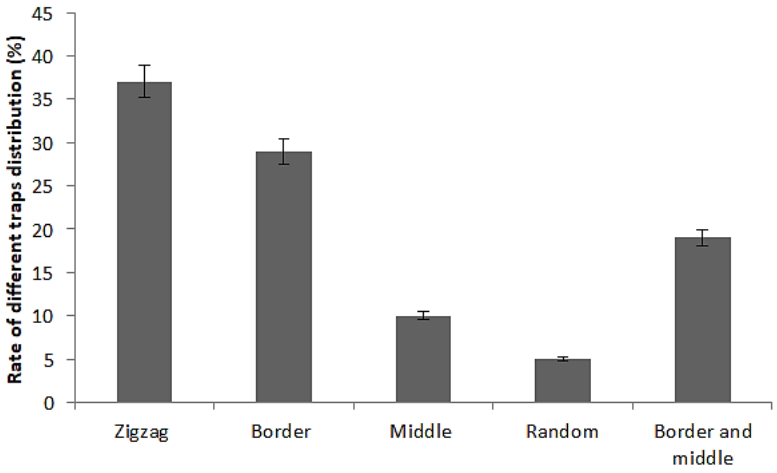

Figure 4. Trap distribution in the orchards surveyed

The treatment threshold for the total farmers investigated was an average of 4 flies per trap daily, regardless of the sex caught. For the exporters, ONSSA requires to install and monitor the traps every day, but the intervention threshold should be applied once 0.5 female flies, or 1 male/day/average number of traps used. Our results revealed that 7% of the farmers surveyed started a chemical treatment against medfly once one fly is captured by trap (Figure 5), 33% started the treatment after capturing 2 or 3 flies per trap and only 53% treated when the catches exceed 3 flies per trap, due to the high cost of pesticides.

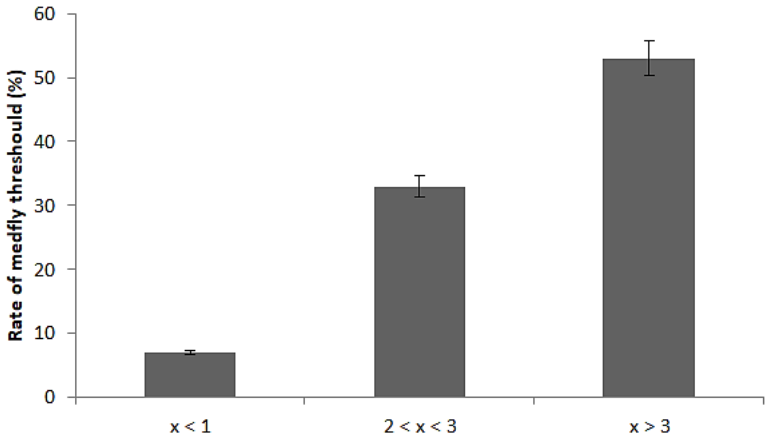

Figure 5. Percentage of farmers according to the intervention threshold (**x** identifies medfly adult per one trap)

However, 79% of citrus producers ensure regular monitoring of fruit infestations only through visual observations of the ceratitis fly presence and fruit bites.

Mass trapping

Pheromone traps

Mass trapping using attractants is an efficient method widely used among the emerging control techniques. In our study, 51% of the citrus farmers investigated in the province of Berkane employed mass trapping of medfly by pheromone using the Ceratrap®, with an average density of 30 traps per hectare. This applied density does not respect ONSSA recommendations which request to use 100 traps per hectare. The number of mass traps employed and the area covered are strongly correlated (r = 0.747). The rest of the farmers, representing 49%, do not practice mass trapping at all. We noticed that the farmers interviewed are subdivided up to 40% of the cost of acquiring female medfly attractants, with the limit of 1000 Dirhams/ha (MAPM, 2015). Asfers et al. (2017) had tried Ceratrap® in peach-nectarine in Morocco from 2012 to 2015 with 84 traps/ha and demonstrated that this trap had a significant performance in terms of limiting damage, in comparison with Magnet-med trap and Femilure CC. However, Ceratrap® was mostly attracting females. In citrus orchards in Tunisia, Hafsi et al. (2019) have shown that the medfly population and rate of fruit damage were significantly lower in Ceratrap® than in Starce® and spinosad treated plots, with a density of 50 traps per ha. The attractant is made of three compounds: Ammonium acetate (AA), Trimethylamine (TMA) and Putrescine (P). This combination provided satisfactory results in orchards and allowed a significant reduction of *C. capitata* populations (Katsoyannosn et al., 2005). These results were also confirmed in Tunisia by Benjemaa et al., (2010) who pointed out the importance of mass trapping using Tri-pack® (20 traps per ha) in the reduction of Mediterranean fruit fly populations in citrus orchards. In mango orchards in Spain, mass trapping by traps baited with AA & TMA in addition to Deltamethrin was the most effective (Ros et al., 2005). The trials carried out on Clementines in Spain by Martinez-Ferrer et al. (2010) demonstrated good efficiency of this technique with a density of 50 traps per ha on mid-season varieties. However, even a density of 75 to 100 traps per ha was not sufficient to protect the

varieties from the beginning of the season, due to the high temperature during this period and therefore a strong medfly infestation. In Morocco, ceratitis control is achieved through the adoption of an integrated pest management program. The program is based on the combination of Femilure (attractant for mass trapping) and insecticide application. This method had been proved as a good control strategy (Mazih, 2011). In 2016, 2017 and 2018 in Moulouya Perimeter of Morocco, Benyazid et al. (2020) demonstrated the importance of including mass trapping in an integrated pest management program. Their results showed a reduction rate of infested clementine fruits compared to the mass trapping applied alone. The efficacy of mass trapping may be affected by many factors, such as trap type, attractant and density, pest pressure, crop practices, geographical isolation and weather conditions (Hafsi et al, 2020a; Hafsi et al, 2020b; Bali et al., 2021).

Straw plugs

Due to the high cost of mass trapping, the use of the straw plug sprayed with a mixture of bait and insecticide remains an alternative solution (Benziane et al., 2003), with some conditions of the appropriate use of this technique. These conditions consist of the optimal volume of straws, their location in the orchard, relative position in the tree, orientation and also the regular treatment of straw with an insecticide and an attractant. Our results demonstrate that 38% of farmers do not use this control technique because of its ineffectiveness (18%) or the lack of awareness (20%). Nevertheless, the majority of farmers (62%) apply this technique with an average density of 82 traps per hectare. As demonstrated in Figure 6, random distribution of the straw plugs is revealed within 45% of the farmers practicing this technique, while 43% opt for a zigzag distribution. The rest of the farmers set the traps in a square at the orchards' borders (8%) or diagonally (4%).

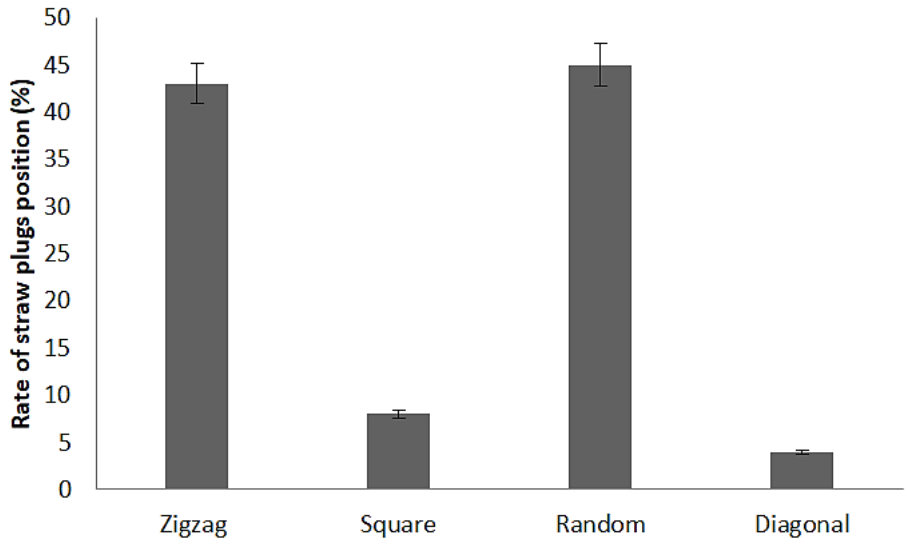

Figure 6. Farmers rate according to the position type of the straw plugs used

The number of straw plugs per hectare is positively correlated with the frequency of chemical treatment of these plugs (r = 0.597). The farmers investigated treat these straws, on average, every 6 days. The products used for this treatment are either a mixture of Lambda Cyhalothrin with Protein Hydrolyzate or based on Spinosad (Success Appât®). Straw plugs were used during the study of Asfers et al. (2017) in

peach-nectarine crops in Morocco and were hanging on the South side of the tree canopy with a density of 1 plug per 3 trees. These plugs were pulverized by Malathion and Protein hydrolyzate when the threshold of 1 male/trap/day is reached or when the rate of infestation was close to 1%. This technique with mass trapping could be an alternative to the exclusive use of insecticides and to reduce the damage of medfly.

Chemical control

The use of pesticides against the medfly, by generalized treatments, is the most control technique used by the farmers interviewed. Seventeen percent of them opt for spot treatment (1 line treated out of 3 lines). An average of 4 treatments are applied against ceratitis before the harvest period and 2 treatments during harvest, but only on straw plugs. Figure 7 demonstrates that 82% of farmers treat at least 3 times before the harvest, while 18% apply up to 6 treatments. On the other hand, during the harvest period, 66% of producers who use straw plugs, treat them only once, and the rest (34%) can go for up to 3 treatments. We discovered the following active ingredients used against ceratitis according to the recommendations of the cooperatives surveyed: Lambda Cyhalothrin at a dose of 100cc/hl + Protein hydrolyzate and Deltamethrin at 50cc/ha; with an average of 6 treatments per campaign against ceratitis. The financial cost of using pesticides can be estimated at 1400 Dh per ha.

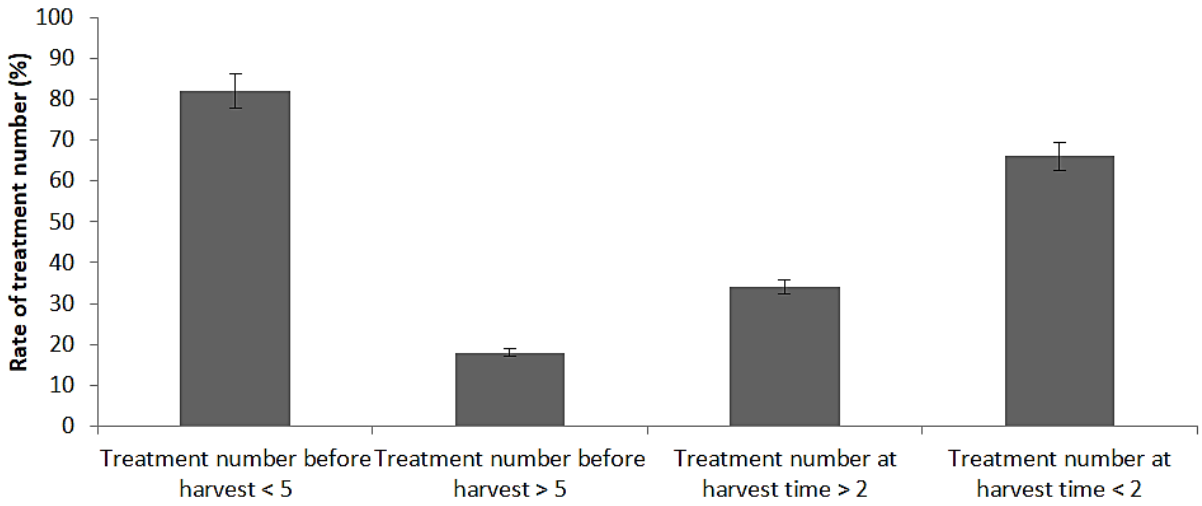

Figure 7. Rate of farmers according to the number of treatments applied before and during the harvest

During our study, we demonstrated the absence of a significant effect of the mass trapping number on the total number of chemical treatments (F = 0.925 ; P = 0.548). It means that the mass trapping does not reinforce the chemical control, which is a result of non-compliance with the recommended density of mass trapping by the farmers interviewed. However, Benyazid et al (2020) have shown that the use of systematic chemical treatment alone, every seven days (eight treatments in total) based on Lambda-cyhalothrin was less effective compared to other treatments that used insecticide with other IPM techniques such as mass trapping. In Tunisia, organophosphate insecticides were used mainly to control this pest, in particular, Malathion because of its inexpensive cost (Boulahia-Kheder et al., 2012). The authors conducted a study in Tunisia that suggested reducing the use of pesticides by applying integrated pest management. According to their results, the control programs applied

against ceratitis in two Thomson Navel Orange orchards presented a good performance, especially when the mass trapping was combined with aerial treatments by Spinosad. The cultural control lead to 2% of pitted fruits damage, compared to 8% of damage after the terrestrial treatments with Organophosphates. To avoid the extensive use of chemical treatments and reduce the level of pesticide residues on fruits, several alternatives have been proposed. Loverde et al. (2011) demonstrated that the application of a Kaolin-based treatment reduced significantly the damage of the medfly, as being an environmentally friendly product and easily detachable from the fruit by simple washing.

Farming practices

The farming practices applied for the medfly management helped on reducing the pest population density and limit its damage. These practices include the elimination of the fruit debris, regardless of whether they have been dropped or remained on the tree after the harvest. The majority of farmers (75% of the interviewed) apply this practice: they bury collected fruits at the depth of 30 cm, throw them out of the farm, and incinerate or crush the residues.

Other phytosanitary problems

During our interviews with citrus growers in the province of Berkane, the farmers raised several constraints. The problems encountered impact heavily the economy of the farms concerned, causing significant damage to the citrus sector. As demonstrated in Figure 8, in addition to the difficulties of the medfly control, 82% of farmers raised the problem of controlling mites. Aphids were claimed by 30%, citrus leaf miner also by 30%, snails by 28% and finally mealybugs by 23%. Regarding the diseases, 61% claimed the *Phytophthora*. The green leafhopper was a new problem claimed by 30% of citrus farmers. Another problem mentioned by 10 % of producers is the confusion between the leaf blotch disease and possible thrips damage, which can go up to 15 % loss in packaging stations.

In a recent study, Lahlali et al. (2021) reported the main pest species in citrus orchards of Gharb and Tadla regions in Morocco, and they showed that the most common pest between the two regions is the mealybug, followed by *C. capitata* and mites (*Panonychus citri* and *Tetranychus urticae*).

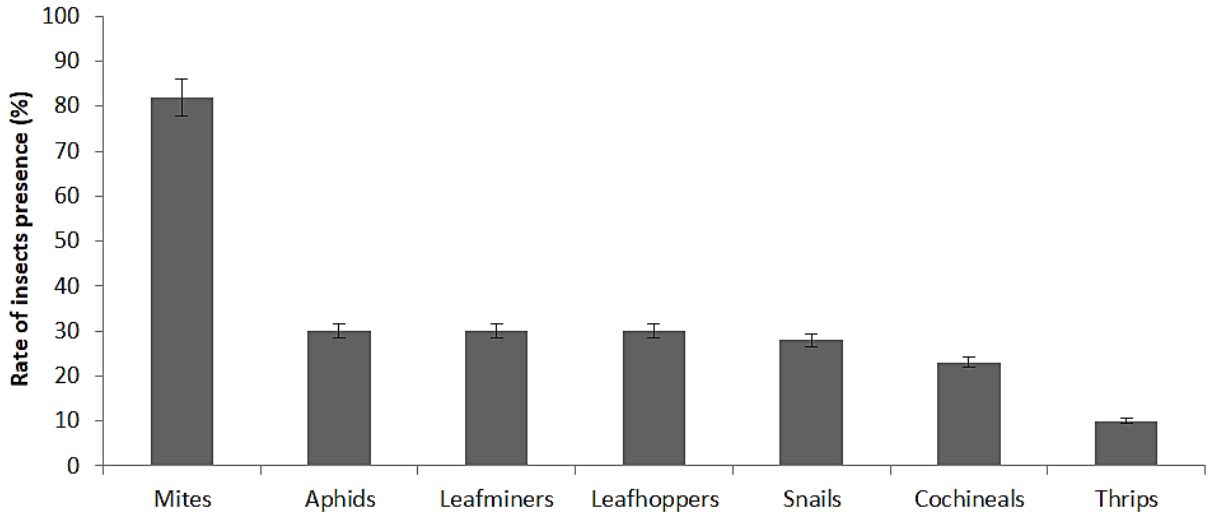

Figure 8. Farmers rate according to the pests claimed

The chemical treatment is the most frequent method applied in citrus orchards. Raising awareness among farmers must be taken into consideration to promote the role of IPM program to control citrus pests and reduce the use of pesticides.

Conclusion

The results obtained provide an insight into the current state of *C. capitata* management in the Berkane region of Morocco, by farmers exporting to the Russian market. These results will be used in future research for the proper management of this pest and for resolving other phytosanitary problems encountered during the surveys.

Conflicts of interest

The authors declare no conflicts of interest.

Acknowledgments

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