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Compte Rendu de la Réunion

at / à
Balandran, France

14th – 16th October, 2006

Edited by:
Fabio Molinari (convenor), Jean Lichou (local organizer) and Emanuele Mazzoni
The content of the contributions is in the responsibility of the authors.
Editorial

The meeting of the Working Group “Integrated Plant Protection in Orchards”, Subgroup “Stone Fruits”, was held in Bellegarde, near Nimes (Gard, France) from 2nd to 4th of October, 2006.

Thanks are due to Jean Lichou, Jean François Mandrin, Alain Garcin, Guillaume Lochard, from Centre Technique interprofessionnel des Fruits et Légumes (Ctifl) - Centre de Balandran.

40 researchers and implementers participated in the meeting. They came mainly from France and Italy but we had also participants from Spain, UK, Germany, Croatia, Greece, Turkey, Jordan.

A total of 43 contributions, including four invited presentations and 16 posters were presented.

The proceedings have been published with considerable delay due to some problems in collecting the contributions.

The invited presentations gave an overview of IPM major problems, followed by some talks on agronomical aspects of IFP. Contributions dealt with pest and diseases in peach, apricot, plum, cherry and almond orchards.

Control means and strategies against pests and diseases, problems to be solved for MD successful application, studies on breeding for resistance of peach to green peach aphid, insecticide resistance in aphid populations and biological aspects of pests and diseases were some of the topics considered.

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Designing a new peach orchard growing system aiming to reduce pesticides and improve profitability

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Abstract: This concept takes current environmental limitations into account by reducing fertilizer and in particular, pesticide use. With sustainable agriculture the main objective is to combine quality with profitability to maintain the future of farms. This orchard system aims to attain these objectives by using a growing system based on regular regeneration and plot rotation.

Adapted tree management ensures reasoned crop protection by reducing the number of treatments and training the trees in a low volume hedgerow allows quantities to be greatly reduced. The trees are not regarded as permanent entities but more as regenerating fruiting supports on which work can be carried out that is easier and that can be mechanised resulting in greater labour efficiency without lowering yields.

Keywords: peach orchard, crop protection, tree training, mechanisation

Introduction

For over 20 years, researchers and technical teams from several countries have explored different ways of improving productivity and profitability in peach orchards. Several ideas have been studied ranging from simply improving techniques to radical changes in orchard design.

Adapting orchard training systems using axial canopies or tying have been tried on peach (Rollin, 1978; Hayden, 1972; Allison, 1987), as well as on other species, which has produced an improvement but not in the long term. Very often, systems aiming for high density are confronted with the problem of excess vigour of trees that have retained their permanent structure (Sansavini, 1980; Hugard, 1981; Loreti, 1991), creating vigorous growth at the top of the tree that makes work on the tree difficult and reduces fruit quality.

At the same time, finding another training system quickly led to prairie orchards in Florida (Young, 1972, 1982), in Israel (Erez, 1978, 1981), and in Italy (Costa, 1993), that
were based on annual cutting back carried out in weather conditions conducive to new growth in the same year. Alper (1984) even designed a harvesting machine. In other circumstances, this concept was applied to protected crops (Bellini, 1985), but couldn’t be adapted to warmer climates.

A preliminary study was carried out at the Ctifl in the 80’s on a fruit farm in the Drôme (South of France) that entailed alternately cutting back one half of the tree. Similar work was carried out in Italy (Costa, 1997). From 1990 onwards, a system of alternate rows being cut back every 2 to 3 years was studied at Balandran; every 3 years being the most efficient. Trees were maintained for 10 years showing the growing system could be permanent.

A new training system – alternate hedge – is being tested at Balandran to see if it can be adapted to peach and if it can improve technico-economic and environmental performances of the orchard. This system should also make work in the orchard easier by reducing the volume of the trees and allowing the use of appropriate mechnisation. This increase in productivity will partly solve the problems linked to labour (availability and technical capacity). The prospect of improving fruit quality is achieved by a lighter tree structure (better light interception) that should have a positive effect on the quality of fruiting branches and fruit.

**Tree training**

The branches are trained into a scaffold that forms a hedge of high density (4 x 1.25m) giving a theoretical density of 2,000 trees per hectare.

Tree management is based on alternate cropping obtained over two consecutive years followed by cutting back the trees the following winter (3rd year). The technique of cutting back trees on a plot every 3 years means that all the trees are regenerated and in particular allows new branches to grow on young structures that improve quality. However, cropping only occurs on 2/3 of the planted area.

This training system does not require a permanent scaffold, meaning that unskilled workers can be used as well as increased mechanization.

Pruning is simplified as in winter only quality shoots on main limbs are kept as well as/ or those on 2-year-old wood and summer pruning (if necessary) consists of trimming with a cutter bar on 2nd-year leaf trees.

Maximum height of the scaffold should not exceed 3 metres (end of 2nd-year leaf).

**Crop Protection Management**

This type of tree management results in distinct phases over the years, alternating between regeneration and cropping. It is to be expected that this influences the incidence of pest and disease development. Apart from crop protection treatments and easier preventive protection, the regeneration period should result in better tree health or at least a reduction in infection potential, as means of infection is usually enhanced on unpruned trees (brown rot and fusicoocum cankers, aphid and mite eggs, scale, even blight and powdery mildew). Certain treatments can be avoided on new growth when no fruit are present. Protection treatments should be applied with equipment using tangential flow to ensure that application is close to the canopy.

Establishing integrated crop protection could be easier because the orchard structure is easier to monitor, allowing better penetration of pesticides with the possibility of reducing spray volume and pesticide drift.
This system therefore provides:
- high density which limits tree growth (easier for workers and machines to reach) and enables the tree to reach an acceptable level of production rapidly;
- cutting back every 3 years which enables all the trees to regenerate and to reduce infection potential, thus increasing tree health and severely reducing chemical treatments (when trees are regenerating no fruit are present on the trees so treatments are unnecessary);
- a restrained shape, a solid fruiting hedge, that offers the possibility of applying chemical treatments with tangential flow equipment closer to the tree canopy to reduce drift.

Combining these management techniques and developing adapted fertilizer and pesticide management, means that an orchard training system integrating all agro-ecological elements can be achieved.

**Design – Establishing the orchard**

**1st year – first-leaf trees**
It is preferable to use scions for planting; as with a conventional orchard they must be cut back when planted. The shape must resemble a scaffold of 3 to 5 branches covered with lateral shoots (on current year’s extension growth) that form a hedgerow. Choose only the most vigorous and upright shoots. Topping may be necessary in June depending on the tree’s vigour.

**2nd – first year of fructification (second-year leaf)**
In the second year when the tree produces fruit for the 1st time, pruning consists of keeping only the best branches. If necessary, thinning may be carried out to reach the yield targeted. Trimming the vertical sides of the hedgerow may be carried out if some of the branches hang down.

**3rd year – second year of fructification (third-year leaf)**
In this year, winter pruning and thinning are carried out. At the end of this year, in February after bud burst, the trees need to be cut back (30 – 40cm high) so that a 3-year cycle can begin as shown in the table below.

**Trial design**

Three mid-season varieties were chosen: ZEEGLO cov, TOPAZE ® and SEPTEMBER STAR according to their range of maturity, their requirements and susceptibilities (storage disease,…).

The trees were planted in winter 2002-2003. In this trial all the trees were planted in the same year which forced us to cut back all the trees in a given plot in winter 2003-2004 (see table below).

<table>
<thead>
<tr>
<th></th>
<th>Plot 1</th>
<th>Plot 2</th>
<th>Plot 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>1st-year leaf</td>
<td>1st-year leaf</td>
<td>1st-year leaf</td>
</tr>
<tr>
<td>2004</td>
<td>new growth</td>
<td>1st fructification</td>
<td>1st fructification</td>
</tr>
<tr>
<td>2005</td>
<td>1st fructification</td>
<td>new growth</td>
<td>2nd fructification</td>
</tr>
<tr>
<td>2006</td>
<td>2nd fructification</td>
<td>2nd fructification</td>
<td>new growth</td>
</tr>
</tbody>
</table>
The agronomical behaviour and labour hours were recorded on each plot of 60 trees making a total of 180 trees per variety.

Results

Over the years, the trees were severely cut back at the end of February/beginning of March, fructification pruning was generally carried out in February.

In 2005 and 2006, two manual prunings were carried out on the regenerating trees so that 4 or 5 main branches could be chosen per tree (this was carried out in 2 stages: 7 or 8 were chosen in May and the final choice of 3 or 4 branches in June).

For the bearing plots, thinning was carried out on 30th May in 2005 and 9th May in 2006. Both sides of the hedgerow were trimmed in 2006 on the 2nd-year leaf plot.

Technico-economic performances

The results presented concern the variety ZEEGLO cov, a yellow fleshed nectarine variety that matures end of July.

Yields

This training system associated with high density produces rapid fruit-setting which means that very high yields are reached from the 2nd-year leaf. From then on yields regularly increased over the years (successive cutting back) as shown in the table below.

<table>
<thead>
<tr>
<th></th>
<th>Plot 1</th>
<th>Plot 2</th>
<th>Plot 3</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>1st-year leaf</td>
<td>1st-year leaf</td>
<td>1st-year leaf</td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>new growth</td>
<td>21.2 t</td>
<td>21.2 t</td>
<td>14.1 t</td>
</tr>
<tr>
<td>2005</td>
<td>35.1 t</td>
<td>new growth</td>
<td>52.8 t</td>
<td>29.3 t</td>
</tr>
<tr>
<td>2006</td>
<td>68.9 t</td>
<td>38.7 t</td>
<td>new growth</td>
<td>35.9 t</td>
</tr>
</tbody>
</table>

Yields produced are promising, but fruit size and labour necessary for this training system need to be taken into consideration.

Labour

Calculating the number of labour hours takes into account time spent on the various management practices: dormant pruning, thinning, using the cutter bar (or grubbing), harvest…. The aim of this trial is to severely reduce labour hours and compensate for a lack of highly skilled workers. It also has the advantage that all the trees are closely pruned every 3 years which requires no particular skill (any error in pruning, etc will not cause problems in the long term) and that all the work is systematized. What’s more, the trimming carried out in June on 2nd-year leaf trees is rapid and makes summer pruning unnecessary.

The following table shows labour hours for 2006.

<table>
<thead>
<tr>
<th></th>
<th>Plot 1: 2nd year of fruiting</th>
<th>Plot 2: 1st year of fruiting</th>
<th>Plot 3: new growth</th>
<th>Average /hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>1,037 h</td>
<td>529 h</td>
<td>100 h</td>
<td>555 h</td>
</tr>
</tbody>
</table>

General total
A labour hours ratio per marketable ton of 15h.36 is obtained (not including workers movement between plots), to be compared with results in traditional orchards.

**Perspectives**

The first results obtained are interesting and correspond to the aims of this trial concerning the lack of labour, unskilled workers, the difficulty of the work, reducing labour hours, maintaining quality and achieving a high ratio between marketable tonnage and labour hours. However, using this training system must be well thought out beforehand as investment costs in the first year are high because of the high density, even though yields obtained in the second year means returns on the investment are good. These results must be compared with the same varieties in traditional orchards.

In spite of these promising results with this growing system, several more years of study are necessary to validate agronomic and economic as well as health performances. Phytosanitary behaviour presented in the objectives will be studied in the years to come.
Observation on leaf mineral composition of sweet cherry trees grown under organic management

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Abstract: the sweet cherry leaf mineral composition of 7 varieties (Colafemmina, Denissens, Drogans, Ferrovia, Pagliarsa, Stark G.G. and Stella) was investigated for the same orchard both during the conventional and the successive organic management. The data obtained for N, P, K, Ca and Mg show clearly a strong influence of management system on leaf mineral contents.

Because the organic management protocol strictly forbidden the use of mineral fertilizers, mainly for which that provide N, a decrease of leaf mineral status was expected over the years.

Really this was observed with the only exception of K which instead increases. The levels of macronutrients found in the leaf of trees under organic management are very unsatisfactory and then a revision of protocol about fertilizers supply could be very desirable.

Key words: leaf diagnostic, organic management, sweet cherry.

Introduction

In Italy, the investigations and studies on sweet cherry under organic cultivation are rather lacking; some of them concern the sensibility of different genotypes to some pests and diseases (Roversi, 1995; Roversi, Monteforte, 2001 and 2005) or the opportunity to protect the fruits against cherry-fly (Caruso, 2004).

Since the protocols for organic production don’t include any use of mineral fertilizers, the mineral nutrition of cherry plants could be a problem.

Just to get some information on this topic, an investigation has been devised in a cherry orchard in South Italy.

Material and methods

In this orchard devoted to grow cherry varieties for cannery, many varieties grafted on different rootstocks are present. In this investigation, we consider 8, 7 out of which grafted only on Mazzard (Colafemmina, Denissens, Drogans, Ferrovia, Pagliarsa, Stark Glorious Gold and Stella) and 3 of them (Colafemmina, Denissens and Montagnola) grafted also on Colt or Mahaleb or Seedling as shown (saw) in the tables. At the beginning (1996) of the study, they were 9 years old, trained to open vase for mechanical harvest, spaced 6x5 meters and drip irrigated in grass mulching soil.

The organic cultivation began in 1998; since then no mineral fertilizers have been supplied; that’s why in the “Protocol” for cherry organic production in Puglia, herbicides, mineral fertilizers and almost all pesticides are strictly forbidden. The ground grasses were cut and left on the soil twice/thrice a year. This kind of ground management increases (Roversi and Monteforte, 2003) the organic matter and, generally speaking, the soil fertility.

* Investigation financially supported by ORTOFRUBIO-MIPA Project
In the owner’s opinion, that was enough to assure good orchard fertilization. Of course, our opinion was very different! For this reason we started to check the plant nutritional status by leaf analysis.

First of all, we considered the soil analysis made in 1995 with 10 replications, for conventional cultivation (CON). In the same orchard position and sample number, we made these analyses again in 2001 that means 3 years before and 3 years after the beginning of organic cultivation (ORG). For each variety and rootstock we selected 3 randomized blocks of 5 plants each, from which we took leaves for chemical analysis. That leaf sampling was repeated on the same plants in 1996 and 1997 for the conventional cultivation, and in 2000 and 2003 for the organic one.

Even if the yielding of the considered varieties in this orchard was not the purpose of this investigation, we obtained some productivity data from the farm records.

**Results and discussion**

**Soil composition**

Tab. 1 shows many variations in the soil analyzed before and during the organic cultivation. The pH significantly increases, which could be due to a high significant increase in exchangeable contents of K, Ca and Mg – see table 1. The active limestone significantly increases.

As expected, after many years of grass mulching soil, an increase in organic matter and total N was observed.

A significant increase was also observed for the contents of assimilable P and Cu. The soluble B and assimilable Mn significantly decrease; on the contrary, a significant increase was also observed for the contents of assimilable P and Cu.

Therefore, it seems that during the period of organic cultivation, the sweet cherry plants have had the opportunity to grow in a more fertile soil.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Conventional</th>
<th>Organic</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.43</td>
<td>7.90</td>
<td>.001</td>
</tr>
<tr>
<td>Active limestone</td>
<td>% 0.67</td>
<td>1.21</td>
<td>.011</td>
</tr>
<tr>
<td>Organic matter</td>
<td>% 1.79</td>
<td>2.43</td>
<td>.007</td>
</tr>
<tr>
<td>Total N</td>
<td>% 1.01</td>
<td>1.32</td>
<td>.029</td>
</tr>
<tr>
<td>P&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;5&lt;/sub&gt; ass.</td>
<td>ppm 6.47</td>
<td>12.88</td>
<td>.002</td>
</tr>
<tr>
<td>K&lt;sub&gt;2&lt;/sub&gt;O exc.</td>
<td>% 282.87</td>
<td>448.63</td>
<td>.000</td>
</tr>
<tr>
<td>Ca exc.</td>
<td>% 364.04</td>
<td>471.05</td>
<td>.000</td>
</tr>
<tr>
<td>Mg exc.</td>
<td>% 151.00</td>
<td>225.38</td>
<td>.000</td>
</tr>
<tr>
<td>B sol.</td>
<td>% 0.69</td>
<td>0.48</td>
<td>.003</td>
</tr>
<tr>
<td>Fe ass.</td>
<td>% 16.05</td>
<td>18.35</td>
<td>.148</td>
</tr>
<tr>
<td>Cu ass.</td>
<td>% 4.77</td>
<td>10.58</td>
<td>.001</td>
</tr>
<tr>
<td>Zn ass.</td>
<td>% 1.07</td>
<td>1.06</td>
<td>.981</td>
</tr>
</tbody>
</table>
**Leaf composition**

a) 7 varieties grafted on Mazzard

The leaf mineral composition of 7 sweet cherry varieties as influenced by orchard management (conventional or organic) is illustrated in table 2.

Such data show clearly that the mineral contents in the leaves sampled on the plant under organic cultivation is lower than the leaves sampled during conventional cultivation, even if the differences are often not significant. The unique exception is K for which the leaves sampled during the period of organic cultivation is higher than the conventional one.

The more important differences (see table) are observed for Ca and Mg and their high level could explain the K lack in the leaf sampled during conventional cultivation vs. the content of leaves sampled during that organic.

The comparison of the elements content in the leaves with the adequate reference level from bibliography (mentioned below in brackets), shows that the level found in the leaves from conventionally cultivated plants are generally not satisfactory for N (2.2-2.6 %), K (1.6-3.0 %) and Mg (0.3-0.8 %), and high for Ca (1.4-2.4%). Of course, the levels found in the leaves sampled from plants under organic cultivation are very unsatisfactory.

b) 3 varieties grafted on different rootstock.

Furthermore, the leaves of varieties grafted on 4 different rootstocks were also analyzed - Tab. 3.

The rootstocks considered were Colt and Sedding (for the varieties Colafemmina, Denissens and Montagnola), Mazzard (for the varieties Colafemmina and Denissens) and Mahaleb (only for Montagnola variety). The data in Table 2, with some exceptions, confirm the results previously submitted and discussed.

While the level of mineral element observed for the 7 varieties grafted on Mazzard, in this case (Table 3) the N level in the leaf of Colafemmina/Mazzard (2.23 %) and Denissens/Seedling (2.28 %) in conventional production is acceptable; on the contrary, for the same variety/rootstock combination, in the organic production, it is lower and close to border level with 1.74 % and 1.81 % values, respectively.

Again, the leaf K level in Colafemmina and Denissens grafted on Seedling in contrast with Montagnola and the other rootstocks don’t decrease in organic production vs. conventional one.

However, with exception of the above-mentioned examples of K, the level of mineral elements in sweet cherry leaves is often lower than adequate levels both for conventional and organic production. The latter strongly decreases the level of mineral elements in the leaves.

**Yielding**

From farm records we observed that the most productive variety was Stella and the lowest was Stark Glorious Gold. We also noticed that in 1998 (end of conventional production) the minimum yielding was 3.0 ton/ha and the maximum 8.0 ton/ha as an average of the 7 varieties considered. In 2003, (5 years after the beginning of organic production) this data reaches respectively 9.0 and 12.0 ton by hectare, which means about 20 % lower than the expected yielding (considering age of plants and orchard location) if the organic production was not introduced.

These results clearly show that the organic production causes a strong decrease of leaves nutritional status with the only exception for K. Despite to this decrease, the loss of yielding was not so important and acceptable for organic production management.

Anyway, we report only the data related to the 5 first years of organic production and we could expect that the leaves nutritional status will be worse in the following years. Without
any mineral fertilizer supply, it will seem indeed very difficult to recover the quantity (Roversi and Monteforte, 2005; Ughini and Roversi, 2005) of mineral elements that sweet cherry plants uptake annually from the soil.

So, a revision of strong fertilization limits in the “Protocol” of cherry organic production could be very desirable.

Table 2. Sweet cherry leaf composition as related to orchard management and varieties.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Nitrogen</th>
<th>Phosphorus</th>
<th>Potassium</th>
<th>Calcium</th>
<th>Magnesium</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Con p</td>
<td>Con p</td>
<td>Con p</td>
<td>Con p</td>
<td>Con p</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>p</td>
<td>p</td>
<td>p</td>
</tr>
<tr>
<td>Con p</td>
<td></td>
<td></td>
<td>p</td>
<td>p</td>
<td>p</td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>Con Bio p</td>
<td>p</td>
<td>p</td>
<td>p</td>
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<td></td>
<td>p</td>
<td></td>
<td>p</td>
<td>p</td>
<td>p</td>
</tr>
<tr>
<td>Cullifemina</td>
<td>2.23 1.74</td>
<td>.014 .021</td>
<td>.007 .009</td>
<td>.020 .027</td>
<td>.020 .027</td>
</tr>
<tr>
<td>Denissens</td>
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<td>.003 .009</td>
<td>.033 .031</td>
<td>.001 .002</td>
</tr>
<tr>
<td>Drogons</td>
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<td>.034 .020</td>
<td>.139 .057</td>
<td>.122 .060</td>
<td>.074 .062</td>
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<tr>
<td>Ferovia</td>
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<td>.370 .069</td>
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<td>.046 .044</td>
</tr>
<tr>
<td>Pagliarsa</td>
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<td>.009 .022</td>
<td>.706 .088</td>
<td>.856 .086</td>
<td>.033 .031</td>
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<tr>
<td>Stark C.G.</td>
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<td>.053 .020</td>
<td>.389 .085</td>
<td>.108 .083</td>
<td>.027 .029</td>
</tr>
<tr>
<td>Stella</td>
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<td>.055 .022</td>
<td>.389 .085</td>
<td>.108 .083</td>
<td>.027 .029</td>
</tr>
<tr>
<td>Averages</td>
<td>2.10 1.77</td>
<td>.000 .020</td>
<td>.002 .007</td>
<td>.000 .000</td>
<td>.000 .000</td>
</tr>
</tbody>
</table>
Table 3. Sweet cherry leaf composition as related to cultivar, rootstock and orchard management.

### Colafemmina

<table>
<thead>
<tr>
<th>Rootstocks</th>
<th>Nitrogen</th>
<th>Phosphorus</th>
<th>Potassium</th>
<th>Calcium</th>
<th>Magnesium</th>
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<td>Con</td>
<td>Org</td>
<td>p</td>
<td>Con</td>
<td>Org</td>
</tr>
<tr>
<td>Colt</td>
<td>2.06</td>
<td>1.84</td>
<td>.485</td>
<td>.24</td>
<td>.14</td>
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<tr>
<td>Mazzard</td>
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<td>.104</td>
<td>.21</td>
<td>.19</td>
</tr>
<tr>
<td>Seedling</td>
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<td>1.75</td>
<td>.036</td>
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<td>.15</td>
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<tr>
<td>Averages</td>
<td>2.10</td>
<td>1.78</td>
<td>.024</td>
<td>.21</td>
<td>.17</td>
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</table>

### Denissens

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<th>Potassium</th>
<th>Calcium</th>
<th>Magnesium</th>
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<td>p</td>
<td>Con</td>
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<td>1.76</td>
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<tr>
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### Montagnola

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<th>Phosphorus</th>
<th>Potassium</th>
<th>Calcium</th>
<th>Magnesium</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Con</td>
<td>Org</td>
<td>p</td>
<td>Con</td>
<td>Org</td>
</tr>
<tr>
<td>Colt</td>
<td>2.00</td>
<td>1.83</td>
<td>.563</td>
<td>.19</td>
<td>.14</td>
</tr>
<tr>
<td>Mahaleb</td>
<td>2.04</td>
<td>1.68</td>
<td>.450</td>
<td>.19</td>
<td>.12</td>
</tr>
<tr>
<td>Seedling</td>
<td>2.01</td>
<td>1.71</td>
<td>.008</td>
<td>.21</td>
<td>.15</td>
</tr>
<tr>
<td>Averages</td>
<td>2.02</td>
<td>1.74</td>
<td>.484</td>
<td>.20</td>
<td>.14</td>
</tr>
</tbody>
</table>
Figure 1. Average of sweet cherry leaf mineral contents as related to orchard management.

References


Ughini, V. & Roversi, A. 2005: Fertilizer supplies to different sweet cherry varieties by Szuics’ method. – 5th International Cherry Symposium, June 06-10, Bursa, Turkey, (in press).
Genetic and functional characterization of the peach-Myzus persicae interaction: towards breeding for durable resistance within integrated orchard management

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Abstract: Integrated production of fruit and vegetable species is one major field of research at Avignon INRA centre. Breeding for durable resistance to the green peach aphid, Myzus persicae (Sulzer) and other enemies of peach crop (Prunus persica L. Batsch) has been initiated fifteen years ago. Several sources of resistance are available among wild and domesticated peaches. Because all resistance genitors used in these programmes are of poor agronomic value, improvement of fruit quality is a long-lasting process. In order to avoid the erosion of the level of plant resistance during this process, the detailed analysis of the underlying mechanisms was undertaken. Here, we present some aspects of the work carried out on the genetic and physiological mechanisms of peach resistance to M. persicae. In addition to the analysis of the plant-aphid interaction under the influence of plant genetic factors, the effects of technical operations, such as winter pruning or nitrogen fertilization, on the aphid population dynamics are being investigated. Varietal resistance combined to cultural practices can be considered as an ultimate strategy to increase the efficacy of aphid control in orchards.

Key words: green peach aphid, peach leaf curl, powdery mildew, sharka disease, host plant resistance, cultural practices, nitrogen fertilization, winter pruning

Introduction

The green peach aphid, Myzus persicae (Sulzer) is a major pest of peach and nectarine (Prunus persica L. Batsch) in southern Europe. Intensive chemical spraying has led to the development of cross resistance to most families of insecticides in aphid populations (Guillemaud et al., 2003). Now, control of M. persicae populations mainly relies on neonicotinoid insecticides. However, the use of such molecules has become a debated question because of their possible negative impact on natural enemies (Suchail et al., 2000) and the appearance of tolerant forms of M. persicae (Foster et al., 2003). The need for insecticide treatments against M. persicae also prevents alternative control methods of other pests, e.g. sexual confusion against the oriental moth Cydia molesta, to be adopted.

A breeding programme for improvement of resistance to M. persicae has been undertaken in the late seventies at INRA Bordeaux (Monet et al., 1998). It has been continued in Avignon and extended to resistance to peach diseases (Kervella et al., 1998, Pascal et al., 1998), including powdery mildew (Foulongne et al., 2003), peach leaf curl (Viruel et al., 1998, Warlop et al., this workshop), and sharka disease (Pascal et al., 2002a; Decroocq et al., 2005). Several sources of resistance against M. persicae have been identified in wild and
domesticated peaches. Because all these resistance genitors are of poor agronomic value, improvement of fruit quality is a long-lasting process also taken into account in the breeding programmes (Moing et al., 2003, Quilot et al., 2004a,b). In order to avoid the erosion of the level of plant resistance during this process, as was observed in the case of powdery mildew (Foulongne et al., 2003), the detailed analysis of the underlying mechanisms was undertaken (Sauge et al., 1998a, 1998b).

Here, we present some results on the genetic and physiological basis of resistance to *M. persicae* in the peach rootstock Rubira® and the wild species *Prunus davidiana*. In Rubira, strong antixenosis resistance is controlled by a single, dominant gene (Pascal et al., 2002b). This cultivar displays a high level of induced resistance two days after aphid infestation (Sauge et al., 2002, 2006). We have exploited this trait to investigate plant responses induced by aphid herbivory by the mean of HPLC analyses targeted on the major pools of primary and secondary metabolites. The results obtained allowed us to formulate hypotheses on the putative effectors of plant resistance. By contrast, *P. davidiana* confers only partial aphid resistance. Analysis of segregation data in the interspecific progeny *P. davidiana* × *P. persica* suggested a polygenic inheritance of resistance. We describe the biological function of two of the genetic factors (or QTL) that have been identified.

### Material and methods

**Comparative metabolomics of Rubira and a susceptible cultivar after aphid infestation**

We used targeted HPLCs to analyse the plant response in the resistant Rubira and the susceptible cultivar GF305, 48 hours after aphid infestation. We also performed HPLC profiles on control (non-infested) plants, so that 4 conditions were available: Resistant-control, Susceptible-control, Resistant-infested, Susceptible-infested. We performed infestation by placing 20 wingless adult aphids on the growing shoot apices. We used 25 plants per condition pooled in 5 replicates.

Shoot apices were lyophilised and metabolites extraction was performed in 70% ethanol in cold, from 50 mg of dry weight. Carbohydrates, amino acids, cyanogenic compounds and phenolic compounds were analysed. Phenolic compounds were separated and characterized by HPLC coupled to negative-electrospray mass and diode array detections.

**Plant material derived from *P. davidiana* and phenotypic assessment of resistance**

A progeny of 77 hybrids (called SD) was obtained from an interspecific cross between *P. persica* var. Summergrand® and *P. davidiana* clone P1908. Summergrand is a yellow nectarine with favourable agronomic characters chosen as recipient genetic material in a breeding programme. *P. davidiana* produces fertile hybrids when crossed with *P. persica*.

This population was evaluated for aphid resistance 46 times in 7 independent trials, between 1991 and 1999 under several environmental conditions (i.e. in the orchard, under insect-proof shelter, in the greenhouse, or in the growth chamber / at juvenile or adult stage / with natural or controlled infestation / with aphid populations or a single aphid clone). Plant infestation was scored by observing aphid abundance and intensity of rolling symptoms on apices and leaves, using two rating scales ranging from 0 (no aphid, and no rolled leaf = most resistant) to 4 (numerous aphid colonies on apices and stems, and leaves and apices rolled severely = most susceptible).

Genotyping was described by Foulongne et al., (2003). Due to lack of polymorphism within *P. davidiana* var. Summergrand, we could only build a map for *P. davidiana*. Because of non-normality of some scores, the presence and effects of QTL were inferred by stepwise forward linear regressions, performed independently for each of the 46 ratings.
Results and discussion

**Plant responses induced by aphid infestation in the monogenic source of resistance Rubira**

Despite the development of aphid colonies and the emergence of typical leaf-curling symptoms, no obvious differences were detected between metabolic profiles of infested and non-infested plants in the susceptible GF305. By contrast, clear-cut changes in the HPLC profiles were observed in Rubira following infestation (Figure 1). A marked decrease was observed for carbohydrates (for sorbitol, $14.2 \pm 2.0 \text{ mg.g}^{-1} \text{ DW on control vs. } 5.7 \pm 1.3 \text{ mg.g}^{-1} \text{ DW on infested plants}$; for sucrose $16.8 \pm 1.8 \text{ mg.g}^{-1} \text{ DW on control vs. } 10.9 \pm 0.9 \text{ mg.g}^{-1} \text{ DW on infested plants}$, for inositol $12.8 \pm 1.4 \text{ mg.g}^{-1} \text{ DW on control vs. } 9.0 \pm 0.5 \text{ mg.g}^{-1} \text{ DW on infested plants}$) and most organic acids (for oxalate, $420 \pm 100 \text{ µg.g}^{-1} \text{ DW on control vs. } 250 \pm 30 \text{ µg.g}^{-1} \text{ DW on infested plants}$). Several amino acids, including lysine ($32 \pm 9 \text{ µg.g}^{-1} \text{ DW on control vs. } 368 \pm 59 \text{ µg.g}^{-1} \text{ DW on infested plants}$) and branched-chain and aromatic amino acids, showed a large accumulation whereas levels of glutamine ($935 \pm 92 \text{ µg.g}^{-1} \text{ DW on control vs. } 301 \pm 41 \text{ µg.g}^{-1} \text{ DW on infested plants}$), proline ($2305 \pm 239 \text{ µg.g}^{-1} \text{ DW on control vs. } 1853 \pm 178 \text{ µg.g}^{-1} \text{ DW on infested plants}$) and threonine ($508 \pm 48 \text{ µg.g}^{-1} \text{ DW on control vs. } 409 \pm 34 \text{ µg.g}^{-1} \text{ DW on infested plants}$) were greatly reduced.

![F1 & F3 axes: 62.13%](image)

Fig. 1. Principal component analysis on 43 metabolites analysed by targeted HPLC in control (c) and *Myzus persicae*-infested (i) shoot apices of the resistant Rubira (R) and the susceptible GF305 (S) peach cultivars.

Aphid infestation of Rubira also triggered accumulation of secondary metabolites, including phenolic and cyanogenic compounds. Hydroxycinnamic derivatives and flavonols were the main phenolic groups detected (Figure 2).

These results allow to formulate several hypotheses on the possible mechanisms involved in induced resistance in Rubira (Poëssel *et al*., 2006): (i) repulsive or toxic factors; (ii) osmotic choc due to a marked decrease in the content of several osmoregulators (proline, sorbitol and inositol); (iii) alteration of the nutritional quality of the food source due to the reduction in glutamine content; this amino acid has been shown to be important for the development of *M. persicae* (Karley *et al*., 2002). These hypotheses are under investigation.
Particularly, bioassays are being performed to evaluate the biological activity of phenolic compounds, and the effect of balance in amino acids in artificial rearing diets.

Fig. 2. HPLC chromatogram of phenolics from Rubira shoot apices infested by *Myzus persicae*. Detection at 330 nm. Compounds 4 and 6 are flavonols, others are hydroxycinnamic derivatives. Compounds 2 to 7 showed a significant increase after infestation by aphids.

**Elucidation of QTL effects in the polygenic source of resistance P. davidiana**

Table 1. *Myzus persicae* resistance QTL detected in SD progeny. Identification of markers of *Prunus davidiana* map most strongly associated with genotype at the five resistance factors for 46 evaluations.

<table>
<thead>
<tr>
<th>Marker</th>
<th>Linkage group</th>
<th>Number of detections</th>
<th>$P^y$</th>
</tr>
</thead>
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<tr>
<td>FG26</td>
<td>5</td>
<td>13</td>
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</tr>
<tr>
<td>Q06-350</td>
<td>3</td>
<td>46</td>
<td>$6.4 \times 10^{-14}$</td>
</tr>
<tr>
<td>A2-1911</td>
<td>2</td>
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<td>0.0003</td>
</tr>
<tr>
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</tr>
<tr>
<td>AA3578</td>
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<td>10</td>
<td>0.0025</td>
</tr>
</tbody>
</table>

Fig. 3. Distribution of *Myzus persicae* resistance (mean score of 46 evaluations) in SD progeny.
Conclusion

Peach genotypes of good agronomic value, and resistant to both powdery mildew and *M. persicae*, are now available after 6 generations of crossing and selfing. Aphid resistance in these genotypes comes from the botanic cultivar Weeping Flower Peach (WFP) (Monet et al., 1998), which exhibits like Rubira antixenosis controlled by a single, dominant gene (Monet & Massonié, 1994). However, it is currently unknown whether resistance in WFP and Rubira results from the same gene. Given that phenotypic expression of resistance slightly differs, the biochemical analysis of resistance, as was undertaken in Rubira, is now required in WFP to determine whether the differences observed are associated to distinct physiological mechanisms. Combining different mechanisms, either in a same genotype or in the orchard through cultivars mixture, could enhance the durability of resistance (Mundt, 2002). Other promising genotypes derived from *P. davidiana* with resistances to *M. persicae*, powdery mildew, peach leaf curl, and sharka disease, have been obtained after three generations of crossing by commercial cultivars. Additional generations are necessary to cumulate resistance factors and good agronomic characteristics. QTL analysis and ecophysiological modelling of fruit quality (Quilot et al., 2004a,b) should help to increase the genetic gain by time unit.

In addition to breeding activities, the effect of cultural practices such as winter pruning or nitrogen fertilization on the population dynamics of *M. persicae* (and consequently the effect of aphid development on fruit quality) is currently under investigation (Grechi et al., this workshop). One particular objective is to better understand the effect of nitrogen fertilization on the plant (i.e. aphid food source) quality, and to evaluate to which extent nutrient treatment may interact with the known genetic-based expression of resistance. Ultimately, integrated management, e.g. through reduction of aphid population size and imposition of disruptive selection via technical operations, may increase the durability of plant resistance.

References


Evaluation of some insecticides against the peach trunk aphid,
*Pterochloroides persicae* (Cholodkovsky) (Homoptera: Lachnidae),
on peach in Jordan

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Ash-Shoubak University College, Al-Balqa’ Applied University, As-Salt 19117, Jordan.
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**Abstract:** Experiments were carried out in Ash-Shoubak on 10-year old peach trees, *Prunus persica* (L.) that were infested with the peach trunk aphid. The efficacy of five insecticides was tested against this insect by spraying the trunk and main lateral branches of the infested trees. The tested insecticides were; Confidate® (a.i., Imidaclorpid), Chlorcyrin®(a.i., Chlorpyrifos & Cypermethrin), Patron®(a.i., diflubenzuron), Trivap®(a.i., Cyromazine) and Vapcomor®(a.i., Acetamprid). All of these insecticides were applied in June and August 2006. Data on nymph and adult mortality have been observed after 2, 7 and 14 days of insecticides application. Only Vapcomor® did not reduce aphid population significantly compared with the untreated control. Both Confidate® and Chlorcyrin® resulted in the highest significant mortality of both nymphs and adults. The present study suggests that both insect growth regulators, Patron® and Trivap®, are potentially important biorational insecticides in the integrated management of the peach trunk aphid.

**Key words:** Peach, Peach trunk aphid, *Pterochloroides persicae*, Chemical control, Insect growth regulator.

**Introduction**

Peaches (*Prunus persica* Siebold & Zuccarini) are widely grown for both commercial markets and home use (Stoetzel & Miller, 1998). In 2005, more than 441128.4 dunums were under stone fruit cultivation in Jordan (Statistical Year Book, 2005). The aphid fauna associated with peaches in Jordan includes at least three species that commonly colonize the trees (Mustafa & Al-Momany, 1994). Peach trunk aphid, *Pterochloroides persicae* (Cholodkovsky), is known also as clouded peach bark aphid and cloudy-winged peach aphid (Stoetzel & Miller, 1998). Principle hosts include *Prunus* spp. (almond, apricot, peach), however *P. persicae* has also been recorded to attack other plants including *Citrus* and *Malus*. *P. persicae* is found living on large branches and trunks of its host (Blackman & Eastop 1994). Large populations of *P. persicae* occurring on the bark can cause fruit not to develop or premature fruit drop; this species produces large amounts of honeydew and is tended by ants (Stoetzel, 1994). *P. persicae* is not listed as transmitting a virus (Chan et al., 1991).

The purpose of the present work is to evaluate the efficacy of some insecticides against the peach trunk aphid in Ash-Shoubak area.

**Materials and methods**

The efficacy of five insecticides on nymphs and adults of the peach trunk aphid was studied on 10-year old peach trees, in the Agricultural Station of Ash-Shoubak University College in the Ash-Shoubak area 220 km south of Amman, Jordan (elevation ca. 1300 m above sea...
level). These insecticides were: (1) Confidate®, (2) Chlorcyrin®, (3) Patron®, (4) Trivap® and (5) Vapcomor®. The common names, trade names, % active ingredients, formulation, group and application rates of the tested insecticides are presented in Table 1. Control treatments in which trees were sprayed with water were used in each spray. Orchardists were requested not to interfere with any practice so as to keep the selected trees as comparable as possible. All treatments were applied twice in June and August 2006. The orchard was subdivided into four plots. Each plot contained a mixture of stone fruit trees. Treatments were distributed according to a randomized complete block design. Each plot was considered as a block and one tree was selected as a replicate in each block for each treatment. All treated and control trees were pruned in February 2006. Twenty adults and 20 nymphs were chosen randomly from each treated or control tree and checked for mortality. Numbers of dead and alive nymphs and adults were recorded after 2, 7 and 14 days of insecticides application. Then percents of mortality were statistically analyzed after angular transformation $\left( \sin^{-1} \sqrt{x} \right)$ using the Least Significant Differences at 95% confidence level.

An analysis of variance was used to evaluate data (SAS - Statistical Analysis System version 8, 2001) after data were exposed to the univariate test of normality. Mean separation was made by using Least Significant Differences test (LSD).

<table>
<thead>
<tr>
<th>Common name</th>
<th>Trade name</th>
<th>% a.i.</th>
<th>Formulation</th>
<th>Group</th>
<th>Rate of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imidaclorpid</td>
<td>Confidate®</td>
<td>200 g/L</td>
<td>SC</td>
<td>Nitroguanidine</td>
<td>20 ml/20 L</td>
</tr>
<tr>
<td>Chlorpyrifos &amp; Cypermethrin</td>
<td>Chlorcyrin®</td>
<td>500 g/L +50 g/L</td>
<td>EC</td>
<td>Organophosphate / Pyrethroid</td>
<td>20 ml/20 L</td>
</tr>
<tr>
<td>Diflubenzuron</td>
<td>Patron®</td>
<td>25 % w/w</td>
<td>WP</td>
<td>IGR</td>
<td>8 g/ 20 L</td>
</tr>
<tr>
<td>Cyromazine</td>
<td>Trivap®</td>
<td>75 % w/w</td>
<td>WP</td>
<td>IGR</td>
<td>3 g/ 20 L</td>
</tr>
<tr>
<td>Acetamiprid</td>
<td>Vapcomor®</td>
<td>20 % w/w</td>
<td>EC</td>
<td>Neonicotinoid</td>
<td>5 g/20 L</td>
</tr>
</tbody>
</table>

**Results**

**June spray**

After 2, 7 and 14 days of insecticides application, the greatest adult mortality was obtained due to spraying both Confidate® and Chlorcyrin®, while both insect growth regulators (IGRs), Trivap® and Patron® showed no significant effect against the adults (Table 2). Spraying Vapcomor® resulted in the lowest significant mortality percents of adults after 2 and 14 days post-treatment (Table 2).

After 2, 7 and 14 days post-treatment examination, all the tested insecticides reduced significantly the insect nymphs, but Vapcomor® resulted in the lowest mortality (Table 3). After 14 days, Confidate® and the two IGRs gave the greatest mortality to the insect nymphs (Table 3).
Table 2: Percent mortality means of *P. persicae* adults infesting peach trees in Ash-Shoubak in June 2006.

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>Mortality means of PTA adults (± SE)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>After 2 days</td>
<td>After 7 days</td>
</tr>
<tr>
<td>Confidate®</td>
<td>61.00±² ± 2.56 (76.25)†</td>
<td>66.75±³ ± 3.09 (83.75)</td>
</tr>
<tr>
<td>Chlorcyrin®</td>
<td>57.75±² ± 0.75 (71.25)²</td>
<td>70.75±³ ± 2.39 (88.75)</td>
</tr>
<tr>
<td>Patron®</td>
<td>11.00³ ± 3.85 (5.00)</td>
<td>12.25³ ± 4.25 (6.25)</td>
</tr>
<tr>
<td>Trivap®</td>
<td>13.50³ ± 4.94 (7.50)</td>
<td>13.50³ ± 4.94 (7.50)</td>
</tr>
<tr>
<td>Vapcomor®</td>
<td>30.00³ ± 4.42 (26.25)</td>
<td>27.25³ ± 4.80 (22.50)</td>
</tr>
<tr>
<td>Control</td>
<td>6.50³ ± 3.75 (2.50)</td>
<td>11.00³ ± 3.85 (5.00)</td>
</tr>
</tbody>
</table>

* Means within the same column that have the same letters are not significantly different using Least Significant Differences LSD.
† Means between parentheses are real mortality percents and analysis was done after percentages were modified using angular transformation (sin⁻¹√x).

Table 3: Percent mortality means of *P. persicae* nymphs infesting peach trees in Ash-Shoubak in June 2006.

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>Mortality means of PTA adults (± SE)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>After 2 days</td>
<td>After 7 days</td>
</tr>
<tr>
<td>Confidate®</td>
<td>76.75a ± 5.51 (92.50)†</td>
<td>75.50a ± 5.63 (91.25)</td>
</tr>
<tr>
<td>Chlorcyrin®</td>
<td>67.00b ± 4.08 (83.75)</td>
<td>75.25a ± 6.81 (90.00)</td>
</tr>
<tr>
<td>Patron®</td>
<td>41.25d ± 1.44 (43.75)</td>
<td>64.50b ± 4.97 (80.00)</td>
</tr>
<tr>
<td>Trivap®</td>
<td>45.00d ± 1.22 (50.00)</td>
<td>68.50d ± 2.18 (86.25)</td>
</tr>
<tr>
<td>Vapcomor®</td>
<td>30.00e ± 1.22 (25.00)</td>
<td>25.50d ± 2.59 (18.75)</td>
</tr>
<tr>
<td>Control</td>
<td>7.75f ± 4.58 (3.75)</td>
<td>11.00f ± 3.85 (5.00)</td>
</tr>
</tbody>
</table>

* Means within the same column that have the same letters are not significantly different using Least Significant Differences LSD.
† Means between parentheses are real mortality percents and analysis was done after percentages were modified using angular transformation (sin⁻¹√x).

**August spray**
Both Confidate® and Chlorcyrin® caused a significant reduction in the adults’ populations of this insect after 2, 7 and 14 days of their spraying (Table 4). The two IGRs resulted in no significant mortality effect to the insect adults after 2, 7 and 14 days post-treatment (Table 4).
Even though that Vapcomor \textsuperscript{®} resulted in no significant reduction of adults’ population after 2 days post-treatment examination, but it showed a slight effect after 7 and 14 days (Table 4). Results revealed that all the tested insecticides reduced significantly the insect nymphs after 2, 7 and 14 days, but no significant differences were obtained among both Confidate \textsuperscript{®} and Chlorcyrin \textsuperscript{®} and the two IGRs after 14 days post-treatment examination (Table 5).

Table 4: Percent mortality means of \textit{P. persicae} adults infesting peach trees in Ash-Shoubak in August 2006.

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>Mortality means of PTA adults (± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>After 2 days</td>
</tr>
<tr>
<td>Confidate\textsuperscript{®}</td>
<td>57.00\textsuperscript{a} ± 5.87 (68.75)\textsuperscript{†}</td>
</tr>
<tr>
<td>Chlorcyrin\textsuperscript{®}</td>
<td>58.50\textsuperscript{a} ± 1.93 (72.50)</td>
</tr>
<tr>
<td>Patron\textsuperscript{®}</td>
<td>11.00\textsuperscript{b} ± 3.85 (5.00)</td>
</tr>
<tr>
<td>Trivap\textsuperscript{®}</td>
<td>11.00\textsuperscript{b} ± 3.85 (5.00)</td>
</tr>
<tr>
<td>Vapcomor\textsuperscript{®}</td>
<td>19.00\textsuperscript{b} ± 8.43 (22.50)</td>
</tr>
<tr>
<td>Control</td>
<td>7.75\textsuperscript{d} ± 4.59 (3.75)</td>
</tr>
</tbody>
</table>

* Means within the same column that have the same letters are not significantly different using Least Significant Differences LSD.
† Means between parentheses are real mortality percents and analysis was done after percentages were modified using angular transformation $\sin^{-1}\sqrt{x}$.

Table 5: Percent mortality means of \textit{P. persicae} nymphs infesting peach trees in Ash-Shoubak in August 2006.

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>Mortality means of PTA adults (± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>After 2 days</td>
</tr>
<tr>
<td>Confidate\textsuperscript{®}</td>
<td>62.75\textsuperscript{a} ± 5.39 (77.50)\textsuperscript{†}</td>
</tr>
<tr>
<td>Chlorcyrin\textsuperscript{®}</td>
<td>62.25\textsuperscript{a} ± 3.32 (77.50)</td>
</tr>
<tr>
<td>Patron\textsuperscript{®}</td>
<td>49.50\textsuperscript{b} ± 4.33 (57.50)</td>
</tr>
<tr>
<td>Trivap\textsuperscript{®}</td>
<td>45.00\textsuperscript{b} ± 3.24 (50.00)</td>
</tr>
<tr>
<td>Vapcomor\textsuperscript{®}</td>
<td>30.75\textsuperscript{c} ± 2.25 (26.25)</td>
</tr>
<tr>
<td>Control</td>
<td>7.75\textsuperscript{d} ± 4.59 (3.75)</td>
</tr>
</tbody>
</table>

* Means within the same column that have the same letters are not significantly different using Least Significant Differences LSD.
† Means between parentheses are real mortality percents and analysis was done after percentages were modified using angular transformation $\sin^{-1}\sqrt{x}$. 
**Overall efficacy**

**Adults:** Confidate® and Chlorcyrin® caused the greatest significant mortality to adults of the insect in June and August (Figs 1 and 2), while both IGRs, Trivap® and Patron® showed no significant effect against the adults.

![Figure 1: Overall efficacy of four insecticides on adults of peach trunk aphid (± SE) in June 2006. Means with the same letters are not significantly different using LSD at 95% confidence level.](image)

![Figure 2: Overall efficacy of four insecticides on adults of peach trunk aphid (± SE) in August 2006. Means with the same letters are not significantly different using LSD at 95% confidence level.](image)

![Figure 3: Overall efficacy of four insecticides on nymphs of peach trunk aphid (± SE) in June 2006. Means with the same letters are not significantly different using LSD at 95% confidence level.](image)
**Nymphs:** Confidate® caused the greatest significant mortality to nymphs of the insect in June, followed by Chlorcyrin® and the two IGRs (Fig. 3). In August, no significant differences were obtained between Confidate® and Chlorcyrin® and both of them caused the highest significant mortality to nymphs (Fig. 4). Both IGRs caused a valuable significant control to the insect nymphs (Figs. 3 & 4).

![Figure 4: Overall efficacy of four insecticides on nymphs of peach trunk aphid (± SE) in August 2006. Means with the same letters are not significantly different using LSD at 95 % confidence level.](image)

**Both adults and nymphs:** In June and August, both Confidate® and Chlorcyrin® gave the highest significant reduction in the population of peach trunk aphid, followed by the two IGRs, Trivap® and Patron® (Figs. 5 & 6).

![Figure 5: Overall efficacy of four insecticides on the population (nymphs and adults) of peach trunk aphid (± SE) in June 2006. Means with the same letters are not significantly different using LSD at 95 % confidence level.](image)

**Discussion**

*P. persicae*, a known pest of peaches, other Prunus spp. (e.g. almond, apricot, and plum), and apples (Stoetzel & Miller, 1998), was noticed in Jordan on Prunus persicae and P. domestica in different locations at all seasons, even January (Mustafa, 1983). It has extended its range into Europe and northern Africa (Stoetzel, 1990). Trade between these regions and the United States increases the chance for accidental introduction (Stoetzel & Miller, 1998). The reproductive biology of this insect was studied by Mustafa (1991) on different trees under constant laboratory conditions.
Aphid colonies are easily visible on peach shady branches and trunk parts. The great infestation causes branch decline because of aphid colonies sucking. A few years infestation induces tree decline. Aphids excrete honeydew in abundant quantity that covers plant parts and soil under attacked tree. The presence of honeydew stimulates sooty mould growth and finally flacks like petroleum appear, separately under the tree.

In the present study, five insecticides were tested against nymphs and adults of peach trunk aphid on peach in Ash-Shoubak area. Vapcomore® that is a local formulation of Acetamprid showed to be inefficient in controlling the nymphs and adults of this insect. It resulted in 23 % and 25 % mortality means of peach trunk aphid population (adults and nymphs) in June and August, respectively. It is a systemic insecticide with translaminar activity and with contact and stomach action and acts as an agonist of the nicotinic acetylcholine receptor, affecting the synapces in the insect central nervous system.

Both Chlorcyrin® and Confidate® were highly efficient in reducing the population (nymphs and adults) of peach trunk aphid. Chlorcyrin® that is composed of a mixture of Chlorpyrifos (Organophosphate) and Cypermethrin (Pyrethroid) reduced significantly about 83% and 79% of peach trunk aphid population (nymphs and adults), in June and August, respectively. This insecticide resulted in more mortality in the nymphs compared with adults (81 % and 78 % for adults, and 85 % and 80 % for nymphs, in June and August, respectively).

Confidate® is a trade name of Imidacloprid produced by Vapco company in Jordan. It showed approximately similar efficiency against peach trunk aphid population to that obtained by Chlorcyrin®. The percentage mortality means of both adults and nymphs were 85 % and 80%, in June and August, respectively. Also it was more effective in controlling nymphs (93 % and 85 % in June and August, respectively) than controlling adults (81 % and 75 % in June and August, respectively). Imidacloprid (1-[(6-Chloro-3-pyridinyl) methyl]-N-nitro-2-imidazolodinimine), a broad-spectrum systemic insecticide that belongs to a new class of insecticides, nitroguanidines, and used in soil applications or foliar treatments. This compound acts only on the nicotinergic type of acetylcholine receptors (Abbink, 1991). Many arthropod species showed susceptibility to Imidacloprid such as the green peach aphid, *M. persicae* on peaches (Karagounis et al., 1996) and other aphid species (Palumbo & Kerns, 1994; Stark et al., 1995), whiteflies (Ernst, 1994), noctuids (Lagadic et al., 1993), plant bugs (Mizell and Sconyers, 1992), lacewings (Mizell & Sconyers, 1992), weevils (Marco & Castanera, 1994), scarabs (Drinkwater & Groenewald, 1994), bees (Stark et al., 1995) and wireworms (Drinkwater, 1994).
Although mortality did not occur as quickly, nor as strongly as with Confidate® and Chlorcyrin® the two insect growth regulators (IGRs), Patron® (a.i., diflubenzuron) and Trivap® (a.i., Cyromazine), showed a valuable efficiency against peach trunk aphid. These two IGRs are promising for peach trunk aphid control in peach orchards. They could be implanted with the integrated pest management programs of stone fruits. They were inefficient in controlling adults of peach trunk aphid and this is expected because its known that IGRs do not affect mature insects. They showed the same degree of control to the nymphs that obtained by Chlorcyrin® or Confidate® after 14 days post-treatment. However, spraying the field by these IGRs several times may results in preventing the build-up of aphid population. Cyromazine has a contact action, which interferes with molting. When used on plants, action is systemic: applied to the leaves, it exhibits a strong translamellar effect. Cyromazine proved effective against other insects such as the Colorado potato beetle (Sirota & Grafius, 1994) and the Red-belted clearwing moth (Ateyyat, 2005).

On the other hand, diflubenzuron acts as chitin synthesis inhibitor; and so interferes with the formation of the insect cuticle. This action is quite specific; related biochemical processes, such as chitin synthesis in fungi, and biosynthesis of hyaluronic acid and other mucopolysaccharides in chickens, mice and rats are not affected. It is non-systemic insect growth regulator with contact and stomach action. Mustafa & Ateyyat (2002) recommended Dimilin® that is another trade name of Diflubenzuron for integrated pest management of the citrus leafminer in Jordan.

Acknowledgement

This research was funded by the Deanships of Research in both Al-Balqa’ Applied University. Thanks due to Ali Rafae’a for his field assistance.

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Survey on the presence of “MACE” and “kdr” mutations in populations of the green peach aphid (Myzus persicae) from Emilia-Romagna peach orchards: preliminary results

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ABSTRACT: The green peach aphid (Myzus persicae), is lastly one of well studied insect model to dissect insecticide resistance mechanisms. As a result, a few in-vitro diagnostic tools were added to the traditional in-vivo bioassays to monitor the presence of resistance in populations of this pest. Since different control strategies and different resistance mechanisms are often involved, both biochemical and molecular approaches must be followed. Biochemical assays can be used to assess esterase detoxifying/sequestering activity as well as the acetyl cholinesterase insensitivity to some insecticides. Molecular screening by RFLP-PCR, may be also effectively performed to detect previously identified target site mutations. Herewith we analyzed aphid populations collected in peach orchards from Emilia-Romagna (the most important peach growing area in Italy) for the presence of elevated esterase expression and acetylcholinesterase insensitivity to pirmicarb. Gene mutation occurrence in acetylcholinesterase (S431F) and in voltage-dependent sodium channel (kdr), conferring resistance to dimethylcarbammates and pyrethroids respectively, have been also checked. Information regarding the co-selection of different insecticide resistance mechanisms are thought supporting technical assistance services, to select the most suitable pest management strategies against M. persicae.

Key words: resistance mechanisms, esterases, acetylcholinesterase, resistance management

Introduction

In Italy the peach potato aphid Myzus persicae (Sulzer) (Hemiptera: Aphididae) is considered a key pest for peach orchards but it can also affect open field crops like sugar beet, potato and tobacco. Insecticide resistant populations were previously described (Mazzoni & Cravedi, 2002; Mazzoni & Pavesi, 2004; Bizzaro et al., 2005). Neonicotinoids introduction has greatly reduced the application of any other active ingredients. At now no data of control failure against M. persicae have been reported (Nauen & Denholm, 2005) but in order to preserve neonicotinoid efficacy, it is recommendable to alternate these products with insecticides with different mode of action. Unfortunately in M. persicae populations multiple resistance mechanisms are frequently co-selected.

Focusing the attention mainly on Emilia-Romagna, which is the most important area for peach growing in Italy, we describe the distribution of three well known resistance mechanism: esterases, modified acetylcholinesterase (MACE) and sodium channel insensitivity to pyrethroids (kdr) by applying a multiple/interdisciplinary strategy based on biochemical and molecular techniques.

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**Materials and methods**

**Insects**

*M. persicae* populations used in the present study have been collected between 1997 and 2006 in peach orchards in Emilia-Romagna. The aphids have been transferred to pea seedlings (cv “Meraviglia d’Italia”) at 21 °C and 16:8 L:D photoperiod and here maintained as colonies of parthenogenetic females.

**Biochemical assays**

Biochemical assays to measure total esterases and insensitive AChE have been carried out on the homogenate of each specimen according to literature (Devonshire *et al.*, 1992; Moores *et al.*, 1994; Mazzoni & Cravedi, 2002). Single aphids have been homogenized in phosphate buffer (20 mM; pH 7 with 0.1% Triton X100). Total esterase activity have been measured using 1-naphtylacetate as substrate and acetylcholinesterase activity have been measured with and without a diagnostic dose of pirimicarb (100 µM). Absorbances have been recorded using a microplate reader (Titertek Multiskan Plus MKII).

**Bio-molecular assays**

The presence of the mutation in the paratype sodium channel gene producing the “*kdr*” phenotype as well as the mutation in the acetylcholinesterase gene conferring resistance to dimethylcarbamates (Nabeshima *et al.*, 2003) were investigated by restriction fragment length polymorphism analysis of PCR products following the strategy described by Cassanelli *et al.* (2005).

**Results and discussion**

The results achieved during our study are reported in table 1. 30 populations collected in peach orchards of various district of Emilia-Romagna have been studied. Collected data point out that none of the populations should be considered susceptible according to the esterase based resistance classes as described by Devonshire *et al.* (1992). Almost the totality of the populations have an high or extremely high resistance level produced by overexpression of the esterases FE4/E4.

Also the “*kdr*” resistance is widely diffused as about 2/3 of the populations are at least heterozygous for this mutation.

Modified acetylcholinesterase genotype is less common but nevertheless present in significant percentage: in fact 30% of the analysed populations have this type of resistance; but only 1 out of 30 populations is homozygous for the mutation conferring specific resistance to pirimicarb.

In the following graphs (Fig. 1-3) the distribution (as percentage of cases) of *M. persicae* population according to the resistance mechanisms studied is reported. Considering the link between esterase based resistance and “MACE” resistance, the greatest part of populations (56.6%) are in the class “R2” (Devonshire *et al.*, 1992) and are homozygous “wild type” for the “MACE” mutation and so they are susceptible to pirimicarb. Also most of the populations belonging to the class “R3” have a sensitive acetylcholinesterase (Graph 1). Considering the “*kdr*” mutation the greatest part of the populations (more than 40%) are “*kdr*” positive and can be assigned to the R2 class for esterase based resistance (Fig. 2).

The link between “MACE” genotype and “*kdr*” is shown in graph 3. Populations without modified acetylcholinesterase but “*kdr*” heterozygous are the most common ones (50% of the cases). The other combinations are less present.
According to our results it is quite evident that “kdr” genotypes are quite common. Even if pyrethroids are not greatly considered in IPM guidelines, it must be considered that they are often adopted in conventional farming and moreover this resistance mechanism can affect also natural pyrethrum used in organic farming. The acetylcholinesterase mutation conferring resistance to pirimicarb has a lower frequency and the greatest part of populations are not affected by this mutation so being susceptible to pirimicarb. For this reason and also because pirimicarb is not seriously affected by esterase resistance, the use of this active ingredient could be still considered in resistance management programs against the green peach aphid.

Table 1. Percentages of *M. persicae* strains with different resistance mechanisms, collected from various district of Emilia-Romagna (Legend: S/S = homozygous susceptible; S/R = heterozygous; R/R = homozygous resistant).

<table>
<thead>
<tr>
<th>district</th>
<th>n</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>S/S</th>
<th>S/R</th>
<th>R/R</th>
<th>S/S</th>
<th>S/R</th>
<th>R/R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piacenza</td>
<td>5</td>
<td>0.0</td>
<td>60.0</td>
<td>20.0</td>
<td>80.0</td>
<td>20.0</td>
<td>0.0</td>
<td>40.0</td>
<td>60.0</td>
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</tr>
<tr>
<td>Ferrara</td>
<td>6</td>
<td>100.0</td>
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<td>83.3</td>
<td>16.7</td>
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<td>16.7</td>
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<td>16.7</td>
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<td>Ravenna</td>
<td>13</td>
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<td>84.6</td>
<td>15.4</td>
<td>61.5</td>
<td>30.8</td>
<td>7.7</td>
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<td>Bologna</td>
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<td>20.0</td>
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<td>80.0</td>
<td>20.0</td>
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<td>40.0</td>
<td>40.0</td>
<td>20.0</td>
</tr>
<tr>
<td>Forlì/Cesen a</td>
<td>1</td>
<td>100.0</td>
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<td>100.0</td>
<td>0.0</td>
<td>0.0</td>
<td>100.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>30</td>
<td>3.3</td>
<td>83.3</td>
<td>13.3</td>
<td>70.0</td>
<td>26.7</td>
<td>3.3</td>
<td>30.0</td>
<td>63.3</td>
<td>6.7</td>
</tr>
</tbody>
</table>

Fig. 1. Distribution (% of cases) of modified acetylcholinesterase genotypes (MACE) and esterase resistance classes in the populations of *M. persicae* collected in peach orchards in Emilia-Romagna (Northern Italy) (Legend: S/S = homozygous susceptible; S/R = heterozygous; R/R = homozygous resistant; est.: classes of esterases based resistance).
Fig. 2. Distribution (% of cases) of “kdr” genotypes and esterase resistance classes in the populations of *M. persicae* collected from peach in Emilia-Romagna (Northern Italy) (Legend: S/S = homozygous susceptible; S/R = heterozygous; R/R = homozygous resistant; est.: classes of esterases based resistance).

Fig. 3. Distribution (% of cases) of modified acetylcholinesterase genotypes (MACE) and “kdr” genotypes in the populations of *M. persicae* collected in peach orchards in Emilia-Romagna (Northern Italy) (Legend: S/S = homozygous susceptible; S/R = heterozygous; R/R = homozygous resistant).

Acknowledgements
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References


Des notes sur la préférence de ponte par *Anarsia lineatella* (Lepidoptera: Gelechiidae) sur le pêcher et des autres hôtes en laboratoire

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**Résumé:** La préférence de ponte d’*Anarsia lineatella* (Zeller) es éffectuée par des individus femalles sous la présence des parties differentes du pêcher (*Prunus percica*) mais des autres hôtes aussi, situés dans des cages au laboratoire et sous des conditions stables. Des experiences de double choix sont réalisés en utilisant des parties differentes du pêcher pour la ponte (bourgeons – fleurs, feuilles – bourgeons, fruits – bourgeons). Dans tous les cas un pourcentage plus important des oeufs s’est deposé sur les fruits et les fleurs en comparaison avec celui des bourgeons et des feuilles. Ayant comme intention d’examiner si il y a une préférence particulière de ponte parmi quelques autres variétés du pêcher deux experiences sont réalisés: de deux choix (*Loadel* - *Nectarina*), et de quatre choix (*Loadel*, *Nectarina*, *Everts* et *J. gold*). Dans tous les cases les fruits de *Nectarina* ne sont pas préférés pour la ponte. En plus, deux communs hôtes potentiels qui se cultivent dans la même region de la Grèce du nord (*Malus pumila* et *Prunus domestica*) sont testés avec deux varietés communes (*Loadel* et *Nectarina*). Pendant ces experiences de quatre choix on remarque qu’ un grand pourcentage d’oeufs sont deposés sur les fruits du pêcher en comparaison avec les autres fruits où s’est dispersé le reste des oeufs. Nos recherches nous montrent qu’il existe une préférence particulière de ponte par *Anarsia lineatella* en indiquant les fruits et les fleurs du pêcher comme les plus préférables pour elle. Ce phenomène est très fort et plus specialement, parmi les varietés des fruits qui ont du trichoma. En plus, ce microlepidoptère est capable de deposer un pourcentage des oeufs dispersés sur des autres hôtes qui prennent des characteristiques morphologiques, de préférence, par la femelle, comme la pomme. Ces resultats ont un interêt special et il contribue à des changement possibles à la population dynamique du rural. Alors, il faut tenir compte de cette information à la recherche des facteurs de la phenologie d’*Anarsia lineatella* aux regions où un spectre ample des varietés et des hôtes est présent.

**Mots clés:** *Anarsia lineatella*, préférence de ponte, pêcher, experience de choix, microlepidopter

**Introduction**

*Anarsia lineatella* (Zeller) (Lepidoptera: Gelechiidae) est une insect nuisible du pêcher en Europe Sud et aux Etats Units (Steven *et al.*, 1993), mais aux pays Asiatiques aussi qui sont leurs pays d’origine (Balatsowsky, 1966).

Cette petite microlepidoptere hiverne pendant l’hiver dans des écorces d’une branche où la petite chenille construit sa geleris et un fourreau externe connu comme hibernaqculum. Ces petites chenilles se reveillent pendant le printemps et pénètrent dans les nouvelles pousses pour integrer leur developpement. Il est aussi possible que pendant les mois les plus chauds de l’été un nombre des chenilles se repose pour quelque temps dans les geleries (King et Denman, 1960, Molinari et Zanrei, 2004). En été les chenilles des générations suivantes s’attaquent aux bourgeons et les fruits pour leurs besoins alimentaires. Cette habitude pendant la production des fruits se considère comme le dégât le plus important. En général ce espèce
est considéré d’être oligophagous et c’est avant tout un ennemi du pêcher, qui semble constituer a préférence alimentaire, mais aussi des autres arbes fruitiers à noyau comme le prunier, l’abricotier et l’amandier. Pourtant, des références détaillées concernant l’existence d’une préférence particulière de ponte par les femelles sur des parties différentes du pêcher, ou sur des variétés du pêcher et des hôtes différents n’existent pas.


Malgré le fait qu’en général la population dynamique se montre cyclique d’une année à l’autre en raison des fluctuations de la température (Kocourek et al., 1996, Tomše et al., 2004) et qu’elle est génératrice d’une diversité pendant des périodes de la culture (Zalom et al., 1992); les dernières années en Grèce la présence de ce microlépidoptère se présente stable et les ravages qui se provoque par A. lineatella sont augmentés. En Grèce, A lineatella possède 3, mais parfois 4, générations par an et ca dépend surtout par des conditions du climat. Ainsi A. lineatella devient très importante et avec Grapholita molesta se considèrent les ennemis clés pour l’application des I.P.M. stratégies du contrôle. Malheureusement ces méthodes sont soutenues la plupart des fois sur l’observation aux mâles avec des pièges du féromone, excepté quelques cas qui se réfèrent d’autres espèces comme Adoxophyes. orana, où des modèles phénologiques sont appliqués (Milonas et al., 2001).

Alors, tous les informations spéciales sur la biologie particulière, le cycle évolutif et le comportement d’A. lineatella sont importantes. Dans cette étude nous présentons des éléments de base sur la préférence de ponte après des observations à des expériences de choix au laboratoire.

**Materiels et méthodes**

**Insects**


**Des experiences de choix en labatoire**

Des expériences de double et quatre choix ont accomplis en laboratoire sous des conditions stables (16 heures en lumière et 8 heures en noir, température 25±1°C et 65±5% humidité relative). Les mâles et femelles papillons encoupés, sont transférés dans des cages plastiques (23x23x23cm) pour leur réproduction. Les mâles sont éloignés après la fécondation (3 jours) à des espaces séparés. Dans chaque cage, se sont depose quatre petites cupes plastiques (2x2cm) remplis avec 10% de solution de sucrose et couverts avec capuchons des plastiques. Ces coupes sont dépoussées par une à chaque coin du cage. En plus, chaque capuchon avait un trou au milieu, dans lequel, on avait coiné du cotton dental en forme cylindrique. Ces petits ‘verres du coin’ servaient aux besoins alimentaires des papillons, mais soutenaient aussi le substrat pour la ponte qui était coiné verticalement avec le cotton dental.
Les expériences des double choix s’étaient composé d’ un couple de substrats différents pour la ponte qui se situaient dans chaque coin de la cage plastique. Pour les expériences de quatre choix, nous avons utilisé la même méthodologie, ayant quatre substrats différents pour la ponte, un dans chaque coin du cage.

Comme substrat pour la ponte nous avons utilisé des tiges du pêcher (3-4 cm) avec le substrat équivalent pour les expériences de prédilection (des tiges avec bourgeons nature, des tiges avec deux fleurs, des tiges avec deux feuilles, et des tiges ayant deux fruits). Comme on a déjà cité les tiges ayant chaque substrat différente se sont coïncédés dans le coton dental d’une façon verticale via la couverture des petits verres. Puisque l’âge des fruits de différentes variétés et hôtes était difficile de se synchroniser, la sélection des fruits est effectuée selon la même taille (2.5x4 cm).


Pour des expériences de quatre choix deux combinaisons sont effectués. À la première, quatre fruits de variétés différentes de Prunus persica sont choisis pour la préférence de ponte: 1. Loadel – Everts – J. Gold – Nectarina. Pour la deuxième expérience de quatre choix nous avons testé des fruits par deux variétés commun du pêcher avec deux fruits des hôtes potentiels: Prunus persica (Loadel) - Prunus domestica – Malus pumila - Prunus persica (Nectarina).

Chaque femelle considérée comme une reprise, en plus pour chaque traitement cinq reprises au minimum sont devenues. Chaque jour on calculait les œufs nouveaux qui sont pondus sur chaque substrat à l’aide d’une stéréoscope et on changait le substrat. La solution de sucrose pour les adultes changait s’il était nécessaire.

Analyse statistique
Des différences parmi le nombre moyen des œufs pontés sur chaque substrat pendant les expériences de double choix sont analysées en appliquant un t-test pour des couples différents ($\alpha$<0.05).

Pour les expériences des quatre choix, une analyse de variabilité est devenue ayant comme facteur le type de substrat (One-Way ANOVA), et le HSD test de Tukey ($\alpha$<0.05) est mis en pratique pour la comparaisons des moyennes (Sokal et Rohlf, 1995). Dans tous les cas on a utilisé le S.P.S.S. 1.4. software.

Résultats et discussion

Experiences de double choix
Les éléments obtenus pendant les expériences de choix, en général ont relevé une forte influence par le substrat particulier sur la ponte de préférence des femelles. Ces données après l’analyse statistique sont exprimés aux schémas suivants en tant que le pourcentage des œufs déposés sur chaque substrat pour la ponte.

Comme attendu, pendant la durée des expériences de double choix en testant des parties différentes du pêcher comme substrat pour la ponte, dans tous les cas un nombre, le plus important, des œufs est déposé sur les fleurs et les fruits en comparaison avec les bourgeons et les feuilles (Schéma1, Schéma 2)
Shéma 1: Pourcentage de préférence de ponte par *A. lineatella* sur les fleurs du pêcher et les bourgeons aux expériences de double choix en laboratoire.

Shéma 2: Pourcentage de préférence de Ponte par *A. lineatella* sur les fruits du pêcher et les bourgeons aux expériences de double choix en laboratoire.

Quand *A. lineatella* n’avait pas la possibilité de choisir une organe reproductive perfectionner du pêcher (fleur ou fruit) pour la ponte, elle a choisi de déposer la plupart des oeufs aux fentes des bourgeons. Ainsi par conséquent le pourcentage des oeufs qui s’est déposé sur les nerfs centraux des feuilles était bas (Shéma 3).
Shéma 3: Pourcentage de préférence de ponte par *A. lineatella* sur des bourgeons du pêcher et les feuilles aux expériences de double choix en laboratoire.

Au cas où les femelles pouvaient choisir parmi deux fruits du pêcher, dont le premier avait du trichoma (*Loadel*) et le deuxième n’en avait pas (*Nectarina*), un nombre statistiquement plus important des œufs s’est déposé sur la surface du *Loadel*. De nouveau, la femelle a choisi de déposer les œufs coincés, cette fois ci parmi les trichomes (Shéma 4).


*Des expériences des quatre choix*

Les données obtenus par les deux expériences de quatre choix sont exposés aux tableaux (1) et (2).

On constate que malgré le fait qu’il existe une variation remarquable au nombre moyen des œufs déposés dans tous les variétés différentes du pêcher, les analyse de cette variation montre que le nombre des œufs pontés sur des fruits avec de trichoma est statistiquement élevé (Tableau 1).
À la expérience de quatre choix en utilisant fruits des deux variétés différentes du pêcher (Loadel et Nectarina) avec des Prunes et des Pommes, le nombre des œufs pontés sur la variété Loadel était plus important en comparaison avec tous les autres choix (Tableau 2). Cependant un nombre remarquable des œufs est pondé sur la pomme (Malus pumila), malgré le fait que Malus pumila n’est pas un fruit noyen et jusqu’aujourd’hui n’est pas un hôte d’Anarsia lineatella. En plus, le nombre des œufs pondés sur la prune (Prunus domestica) - qui peut être une hôte alternative - était considérablement plus bas.

Tableau 1: Ponte de préférence par *A. lineatella* exprimée en tant que le pourcentage des œufs deposés sur quatre fruit varieties différentes du pêcher aux experiences de quatre choix en laboratoire.

<table>
<thead>
<tr>
<th>Variétés du pêcher</th>
<th>Pourcentage des œufs deposés</th>
<th>± S.E.M.¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loadel</td>
<td>0.33</td>
<td>0.03b</td>
</tr>
<tr>
<td>Nectarina</td>
<td>0.16</td>
<td>0.01a</td>
</tr>
<tr>
<td>Everts</td>
<td>0.20</td>
<td>0.02ab</td>
</tr>
<tr>
<td>Juhn Gold</td>
<td>0.32</td>
<td>0.04b</td>
</tr>
</tbody>
</table>

¹ Des moyennes dans la même colonne suivies du même lettre ne se différencient pas considérablement, ANOVA et Tukey’s HSD comparaison des moyennes, α=0.05

Tableau 2: Ponte de préférence par *A. lineatella* exprimée en tant que le pourcentage des œufs deposés sur deux variétés du pêcher et deux hôtes potentiels, aux experiences de quatre choix en laboratoire.

<table>
<thead>
<tr>
<th>Hôte</th>
<th>Pourcentage des œufs deposés</th>
<th>± S.E.M.¹</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>P. percicae</em> (Loadel)</td>
<td>0.59</td>
<td>0.05a</td>
</tr>
<tr>
<td><em>P. percicae</em> (Nectarina)</td>
<td>0.17</td>
<td>0.04bc</td>
</tr>
<tr>
<td>Malus pumila</td>
<td>0.19</td>
<td>0.02b</td>
</tr>
<tr>
<td>Prunus domestica</td>
<td>0.5</td>
<td>0.01c</td>
</tr>
</tbody>
</table>

¹ Des moyennes dans la même colonne suivies du même lettre ne se différencient pas considérablement, ANOVA et Tukey’s HSD comparaison des moyennes, α=0.05

Nos recherches nous montrent qu’il existe une préférence particulière de ponte par *A. lineatella* en indiquant les fruits et les fleurs du pêcher comme les plus préférables pour elle. Pendant le printemps les femelles des générations hivernaux est possible de choisir pour la ponte des fleurs des variétés précoces en comparaison avec des bourgeons des variétés retartables qui se trouvent aux espaces avoisinantes. En plus pendant l’été dans une région ou se trouvent en même temps des variétés avec des trichomes comme Loadel et sans trichomes (Nectarina); il est possible que les femelles choisissent pour la ponte les premières ci dessus.

Probablement la morphologie spécifique de la surface d’un substrat pour la ponte, permet d’une part aux femelles de deposer les œufs separement de l’autre d’être protégés dans un
degré à une attaque possible des prédateurs. La morphologie et l’architecture des feuilles et l’arrangement spatial des aiguilles est responsable pour la ponte de préférence de quelques autres lépidoptères aussi (Grant, 2006). En plus, des facteurs particuliers associés avec la variété, peut provoquer une variation à la ponte préférence comme dans le cas de *C. molesta* (Myers *et al.*, 2006). Ainsi, les individus femelles peuvent choisir d’un hôte pour les petites chenilles qui assure développement rapide sans danger (Stavridis et Savopoulou, 1998). Le qualité de la plante peut aussi influencer la capacité de la reproductivité (Ishihara et Ohgushi, 2006). En fin de compte, il est possible, ces caractéristiques morphologiques à la surface du fruit peuvent être perçus via le contact de la surface avec l’ovipositeur, mais le mécanisme particulier qui s’implique à la procedure de la selection du hôte est inconnu et plus d’investigations doivent se réaliser pour prouver cet hypothèse.

**Remerciements**

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Disruption of matings of *Anarsia lineatella* in peach orchards

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**Abstract:** Peach Twig Borer (*Anarsia lineatella*) has been spreading its distribution in stone fruit cultivation areas. In peach orchards the damages of PTB overlap to the ones of Oriental Fruit Moth (*Cydia molesta*). Mating disruption is effective in the control of OFM, while some more inconsistent results are reported against PTB. In fact, even in MD plots it is not uncommon to record male catches in the standard monitoring traps. Studies have been undertaken to define the effect of different ratios of the components of PTB pheromone blend.

The reduction of catches in traps baited with the synthetic pheromone or with virgin females, compared with one control, were recorded in 2 plots where dispensers for MD containing only trans-5-decenyl acetate and both trans-5-decenyl acetate and trans-5-decenol were applied.

The response of males to the same attractants was tested in a wind-tunnel and by EAG analysis.

**Key words:** *Anarsia lineatella*, peach, pheromone, Mating Disruption

**Introduction**

The Peach Twig Borer *Anarsia lineatella* Zeller (PTB), has caused damage in Italian stone fruit cultivation areas where it was not recorded before. In peach orchards the damages of PTB overlap to the ones of Oriental Fruit Moth (*Cydia molesta*). Mating disruption that has proved to be very effective in the control of OFM gives some more inconsistent results against PTB. In fact, even in MD plots it is not uncommon to record male catches in the standard monitoring traps. The main components of the female pheromone are trans-5-decenyl acetate and trans-5-decenol, but there is still some doubt on the best ratio to be used in the synthetic blend. Studies have been undertaken to define the effect of different ratios of the components of PTB pheromone blend on both attractiveness and disrupting power on males.

**Materials and methods**

Two different blends of PTB synthetic pheromone were used for field and laboratory trials: trans-5-decenyl acetate (99%) and trans-5-decenyl acetate (85%) + trans-5-decenol (15%).

**Field trials**

In a peach orchard, three plots were set up, the first with 1000 dispensers/ha, containing trans-5-decenyl acetate (99%), the second with 1000 dispensers/ha, containing trans-5-decenyl acetate (85%) + trans-5-decenol (15%) and the third with no pheromone dispenser.

Traps baited with *Anarsia lineatella* virgin females (fig. 1) and synthetic pheromone lures where applied in each plot, the catches recorded weekly (table 1).
### Table 1

<table>
<thead>
<tr>
<th>Date</th>
<th>Female traps</th>
<th>Pheromone trap</th>
<th>Female traps</th>
<th>Pheromone trap</th>
<th>Female traps</th>
<th>Pheromone trap</th>
</tr>
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<tbody>
<tr>
<td>12/07</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>13/07</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>23</td>
<td>6</td>
<td>21</td>
</tr>
<tr>
<td>16/07</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>23</td>
<td>8</td>
<td>52</td>
</tr>
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<td>19/07</td>
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<td>8</td>
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<td>55</td>
<td>24</td>
<td>130</td>
</tr>
<tr>
<td>24/08</td>
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<td>27/08</td>
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<td>24</td>
<td>12</td>
<td>85</td>
</tr>
<tr>
<td>30/08</td>
<td>1</td>
<td>11</td>
<td>2</td>
<td>10</td>
<td>55</td>
<td>136</td>
</tr>
<tr>
<td>03/09</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>25</td>
<td>110</td>
</tr>
<tr>
<td>06/09</td>
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<td>1</td>
<td>0</td>
<td>4</td>
<td>26</td>
<td>119</td>
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<tr>
<td>10/09</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>6</td>
<td>0</td>
<td>61</td>
</tr>
</tbody>
</table>

The response of males to the same attractants was tested in a wind-tunnel and by EAG analysis.

**Wind-tunnel**

A wind-tunnel for bioassay to observe response of male to odour source was utilized.

The bioassay was a dual choice type to compare the attractiveness of virgin female to two different synthetic pheromones, *trans*-5-decenyl acetate (99%) and *trans*-5-decenyl acetate (85%) + *trans*-5-decenol (15%).

Acetate transparencies with insect glue used as traps were placed at the upwind end of the wind tunnel. Male moths were released in groups of 10 at the downwind end.

A cylindrical cage (h 1.5 cm - Ø 3 cm) with fine mesh were placed at the upwind edge of the traps (fig. 2)

![Figure 1. Trap baited with virgin females](image1)

![Figure 2. Cylindrical cage used in the wind tunnel](image2)
Figure 3. Response of PTB males to a virgin female

Figure 4. Response of PTB males to different doses of 5-decenyl acetate (85%) + trans-5-decenol (15%)

Figure 5. Response of PTB males to different doses of 5-decenyl acetate (99%)
**EAG analysis**

The aim was to verify the EAG response of *A. lineatella* to the same compounds as above and compared it with the response of virgin males to the crude extract of calling female.

The whole head of the insect was inserted in a micropipette (*reference electrode*) and antennal tip (without the last 2-3 segments) was inserted in a similar micropipette (*recording electrode*). Five dilutions of each compound were tested: 0.01 – 0.1 – 1 – 10 – 100 µg/µL.

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**Results**

The response of males has been significant, with a very clear dose-response effect; no significant difference have been recorded among the compounds tested. High sensibility has been recorded at doses 3 and 4 (1 and 10 microliters)
Cherry Fruit Fly - Methodological studies to increase the efficacy of bioassays

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Abstract: Trials carried out for the registration of new products is costly and dependant on the natural infestation level. The aim of the studies presented here, is to perfect a method that makes trials more reliable and less costly. It consists in releasing fruit flies in insect proof bags/sleeves that cover fruit-bearing branches, thus ensuring artificial contamination on relatively small plots. A trial carried out in 2006 showed that 66% of fruit were contaminated in the untreated control, compared to 3.5% of the treated fruit; a control plot showed a natural infestation level of 4%. The fruit flies used for artificial infestation came either from traps in orchards, or were reared in cages using pupae. Developing rearing techniques over a complete life cycle are also being studied for mass insect rearing.

Keywords: Cherry, insect pest, cherry fruit fly, Rhagoletis cerasi, chemical control, rearing, registration, experimental methodology.

Introduction

Cherry fruit fly (Rhagoletis cerasi) is a major pest causing severe damage on cherry. Protecting fruit has become indispensable in the majority of orchards. Only the earliest varieties (Burlat and earlier ones) are rarely affected, because harvest usually occurs before the larvae develop in the fruit. Chemical control is, at the present time, the only effective means of control, as the fresh market expects fruit to be completely free of larvae. The lack of effective chemical insecticides to protect fruit led to an experimental program being created in 2004 (SDQPV, Ctifl, Regional Stations) to discover complementary or alternative control methods. Trials on biological effectiveness have been carried out by different collaborators. In certain plots, damage thresholds were low making it difficult to interpret the results. This led the Ctifl to find ways of improving trial efficacy by managing pest populations.

Trials on pesticide efficacy are usually carried out in fruit-bearing orchards, on small plots of 3 to 5 trees, with, in general, 4 replications per treatment. Treatments are carried out on all the trees in each plot. The products to be evaluated are compared to a control and a reference product. Damage is evaluated on fruit samples collected at harvest. This type of trial usually entails destroying the fruit harvested if the pesticide is not registered, which can be costly. What’s more, the potential for fruit contamination in orchards that regularly receive chemical treatments is variable and is often lower that 1 or 2%. Even though this level is unacceptable for the market, it is not severe enough to evaluate the efficacy of pesticides in experimental plots. Also, the level of pest attack is difficult to forecast because traps assess pest flight and not population numbers. It is therefore frequent with this pest, to set up expensive trials that provide inconclusive results. This has led us to develop an experimental method to enable fruit to be contaminated artificially, thus reducing the uncertainty. This has been achieved by timely release of adults.
Materials and methods

The methodology used in the first year of this work is largely based on the one presented in 1967 for the Mediterranean fruit fly in the CEB method n° 12 (Trial method to test the effectiveness of insecticides used on peach to control *Ceratitis capitata*).

The principle is based on artificial infestation using insect adults that will lay eggs on the fruit. The shoots are then enclosed in an insect proof cloth sleeve and the adult couples are released inside to lay their eggs on the enclosed fruit.

One elementary block is made up of a portion of branch carrying at least 100 fruit within the sleeve.

Three strategies were compared to validate the method:
- Fruit treated with a reference product.
- Non-treated control
- Non-treated control without insect release to establish how natural populations would develop before placing the sleeves on the branches.

Four replicates were undertaken for each treatment.

The trial was carried out on the Noire de Meched variety. The sleeves were placed on the branches on 1st June, the treatment was applied on 7th June and the fruit harvested and examined on 21st June (preharvest interval of 14 days). The sleeves were installed late, at least a week after veraison. As all the fruit had coloured at this point (more than 3 weeks before harvest), eggs may have already been laid by the fly in the fruit (see damage).

Five insect releases were carried out in each sleeve:
- 1 couple 2 days before treatment
- 1 couple the day before treatment
- 5 couples the day of treatment after the product had dried. The sleeves had to be removed for 3 hours for the product to be applied and to allow it to dry. This procedure was also carried out on the non-treated controls. The flies that had already been released therefore were able to escape.
- 3 couples 2 days after treatment
- 1 couple 5 days after treatment.

Obtaining the flies

Two methods were used to obtain the flies that were released in the sleeves:
- adults were captured in orchards
- emerging adults from pupae collected the previous year

In the first method yellow traps were placed in the canopy of infested cherry trees. The traps contained paper soaked in sugared water. Traps baited with ammonium acetate are considerably more attractive to the pest. They must be placed 1 to 3 days before insect release. The captured flies were sexed in the laboratory and had to be released in the sleeves the same day. The efficacy of this method is reliant on population numbers in the trapping orchard, but also on weather conditions during trapping. When there are winds, trapping is less effective. In 2006, only 2 flies were captured per day and per trap. This technique is useful but can prove unreliable and may require a high number of traps.

The second method consists of collecting pupae the previous year and making the adults emerge when needed. To obtain pupae, infested cherries are collected just before the maggot is fully mature when it leaves the fruit: this usually coincides with fruit ripening. The size of
the maggot determines the stage of development. The harvested cherries are placed on trays with a grid base which is placed over a box. The larvae leave the fruit when they are fully developed and fall into the box where they form pupae. They are then collected and placed in Petri dishes a hundred at a time. They are stored at room temperature during the summer and then refrigerated at 4°C from autumn onwards. To allow adult emergence from the pupae they are placed in rearing cages at about 25°C. The adults emerge about 3 weeks later more or less at the same time if the temperature is stable: 70 % emerge within 5 days. After emergence, mating was observed 3 to 13 days later. At this stage the flies are considered to be ready for release in the sleeves. This method is more reliable than trapping adults in the orchard. It is however more time-consuming. In these trials only 35% of adults emerge, which means that 3 times more pupae than necessary need to be collected. In the trial previously described we used 11 couples per sleeve, which corresponds to about 200-250 pupae per treatment (sex ratio 1/1). The level of infestation achieved implies that the number could probably be greatly reduced. Moreover, collecting maggots means that a highly infested orchard is necessary, preferably one that has received no chemical treatments for a number of years.

**Results and discussion**

Damage was evaluated 14 days after treatment, that is 16 days after the first release and 9 days after the last one. All the fruit enclosed in the sleeve were examined. The average number of fruit was 135 per elementary plot (70 for the lowest plot and 281 for the highest). The results are presented in figure 1. It can be seen that the level of natural infestation in this orchard was very high that year, as 14% of fruit suffered damage before sleeves were placed on the branches (non-treated fruit without pest releases). The effectiveness of fly releases is significant; the number of damaged fruit reached 66%, 50% more than the control without pest release. As for the treatment, its efficacy is evident when populations were high, as the difference is significant when compared to the non-treated control with pest release. Note that the differences between the treated plot and the control without pest release are insignificant, because of the high variability between sleeves. These differences and the rate of pest attack are not however insignificant (3.5% of damaged fruit compared to 14%). This illustrates how difficult it is to interpret experimental results with natural populations.

**Figure 1**
**Attempt at rearing**

This experimental method led us to study the possibility of rearing flies over a complete life cycle. This would mean that a certain number of adult pests could be obtained when necessary. Developing rearing techniques consists of controlling the different developmental stages: adult, egg-laying, larvae, pupae. The first phase is identical to the one previously described: storage at 4°C, then at 25°C for emergence. Adults are reared in a plexiglass box with grid openings. A plant was placed inside to ensure that humidity was sufficient. Temperature was between 23 and 27°C. The flies were fed on sugar and water. The life span of the adults in these conditions was from 4 to 6 weeks.

After adult emergence, mating first took place a few days later and egg-laying began 3 weeks later. Egg-laying lasted for about a month, almost throughout the life span of the adults, but it was observed with one batch that 70% of the eggs were laid in 10 days, 3 to 4 weeks after emergence. Egg-laying was achieved on fresh and defrosted cherries. We are working on the development of an artificial egg-laying procedure to be able to collect eggs easily.

Egg hatch took place, on average, after 5 days. In relation to larvae rearing, we tested larval diets described in the references in the bibliography. Our current studies have resulted in obtaining viable eggs that hatch, but the complete rearing cycle has not yet been achieved, nor has mass rearing.

The results obtained from these experiments on pest release in sleeves are promising. They may provide improvements or interesting complementary aid to efficacy trials for insecticides. Already this technique can be used to test the efficacy of products, and if necessary, their effect on adults or larvae, their persistence as well as application strategy. A lower number of fruit can be treated than with standard trial methodology, considering the high pest pressure obtained, which means that less fruit are destroyed. Mass rearing of adults should perfect this technique. We haven’t been able to overcome the problems of managing larval development, which seems to be a sensitive stage for this insect.

The work involved in developing this rearing system has resulted in the acquisition of valuable knowledge on this insect’s biology.

**References**


Efficacité du GF-120 dans la lutte contre la mouche de la cerise

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Résumé: La lutte contre la mouche de la cerise, Rhagoletis cerasi L., constitue un des principaux enjeux techniques de la production de cerise en France. La seule matière active disponible réellement efficace, le diméthoate, est un organophosphoré au profil toxicologique et écotoxicologique sur la sellette. Il est donc primordial de trouver de nouveaux moyens de lutte contre ce ravageur, efficaces et respectueux de l’environnement et de la santé de l’applicateur. La spécialité GF-120 développée par la société Dow Agrosciences pourrait constituer une alternative intéressante au diméthoate puisqu’il s’agit d’un produit innovant associant une substance active insecticide (spinosad) et un attractif alimentaire dans sa formulation. Dans le cadre de la démarche Usages Mineurs coordonnée par le SPV / Ctifl, le Domaine Expérimental La Tapy expérimente ce nouveau produit depuis 2004. Ces trois années d’étude nous ont permis d’affiner le positionnement du produit. Cet adulticide doit être positionné tôt, dès le tout début du vol de la mouche et renouvelé tous les 7 jours afin de couvrir la totalité du vol. Dans ces bonnes conditions d’application, et dans le cas d’une pression du ravageur relativement modérée, le GF-120 présente une efficacité proche du diméthoate.

Abstract (Efficiency of the GF-120 used in the cherry fruit fly management): Cherry fruit fly management is a major concern for French cherry growers. The active ingredient diméthoate currently being used will soon be withdrawn. So it is more than useful to develop new means of control against this pest. GF-120, a plant protection product developed by Dow AgroSciences is effective on adults only. Pesticides used against adults are not very efficient because of the high cherry fruit fly mobility. But GF-120 associates an insecticide (spinosad) and an attractant which helps to solve this problem.

Some experiments have been carried out at the Domaine Experimental La Tapy (Vaucluse, France) since 2004 to test GF-120. We are currently able to define an optimal control program for GF-120. The first GF-120 application must be done from the beginning of the cherry fruit fly emergence, then it has to be repeated every week for the duration of the flight. In those spraying conditions and under a low cherry fruit fly pressure, GF-120 appears to be as efficient as dimethoate.

Mots clefs: Cerise, Rhagoletis cerasi L., GF-120, spinosad, attractif alimentaire.

Introduction

La mouche de la cerise représente un des principaux ravageurs de la cerise en France. La pression du ravageur est variable suivant les régions et les années. Si la législation européenne tolère 2 à 4 % de cerises éclatées ou véreuses, la règle commerciale est plus stricte : aucune tolérance n’est admise quant à la présence de parasites dans les cerises. La lutte contre la mouche de la cerise est donc généralisée à tous les vergers et systématique.

Aujourd’hui, la seule matière active disponible réellement efficace est le diméthoate. Or, à partir de fin 2007, l’emploi de cet organophosphoré risque d’être interdit en raison de son profil toxicologique et écotoxicologique dangereux. Il est donc primordial de trouver de nouveaux moyens de lutte contre ce ravageur, efficaces et respectueux de l’environnement et de la santé de l’applicateur.

**Matériel et méthodes**

Depuis 2004, trois essais d’efficacité du GF-120 ont été réalisés au Domaine Expérimental La Tapy selon le même protocole. Ces essais ont été réalisés dans le cadre du réseau BPE de la station. Trois modalités ont été testées (tableau 1):

- témoin non traité
- traitement avec une spécialité à base de la matière active de référence: le diméthoate
- traitement au GF-120

Tableau 1: Eléments descriptifs des modalités testées.

<table>
<thead>
<tr>
<th>Spécialité phytosanitaire</th>
<th>Mode d’action</th>
<th>Positionnement par rapport au cycle de la mouche</th>
<th>Dose (l/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Témoin non traité</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GF-120</td>
<td>Adulticide</td>
<td>Dès le début du vol ; renouvellement hebdomadaire</td>
<td>1,5</td>
</tr>
<tr>
<td>Dimezyl 40 EC (référence CEB)</td>
<td>Larvicide</td>
<td>Dès les premières éclosions ; renouvellement éventuel</td>
<td>0,75</td>
</tr>
</tbody>
</table>

La protection par le GF-120 doit couvrir toute la période du vol. La première application de GF-120 est prévue dès le début du vol. L’application est renouvelée ensuite toutes les semaines sur la base de 4 traitements par saison. Le traitement est par ailleurs renouvelé en cas de précipitation dépassant 10 mm (risque de lessivage).

Le traitement de référence à base de diméthoate (dans notre cas, nous avons travaillé avec le Dimezyl 40EC) est réalisé une vingtaine de jours après le début du vol pour être positionné au plus près des premières éclosions.

**Le dispositif expérimental**

Tableau 2: Eléments descriptifs des deux vergers d’essai.

<table>
<thead>
<tr>
<th></th>
<th>Parcelle GF-120</th>
<th>Parcelle Témoin non traité + Référence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superficie (m²)</td>
<td>1728</td>
<td>1650</td>
</tr>
<tr>
<td>Variété</td>
<td>Van</td>
<td>Van</td>
</tr>
<tr>
<td>Pollinisateur</td>
<td>-</td>
<td>Burlat</td>
</tr>
<tr>
<td>Porte-greffe</td>
<td>SL 64 et Colt</td>
<td>Divers</td>
</tr>
<tr>
<td>Année de plantation</td>
<td>1985</td>
<td>1989</td>
</tr>
<tr>
<td>Distances de plantation</td>
<td>6 x 3</td>
<td>6 x 5</td>
</tr>
<tr>
<td>Conduite</td>
<td>Gobelet en taille courte</td>
<td>Gobelet en taille courte</td>
</tr>
</tbody>
</table>

Les figures 1 et 2 détaillent le plan de l’essai: la parcelle d’essai GF-120 forme un bloc de 1728 m². Ainsi 96 arbres sont traités avec ce produit. Cette parcelle est entourée au nord, par une haie de cyprès puis de parcelles de blé et de vigne de cuve ; à l’est, par un verger de cerisiers traité au diméthoate ; au sud et à l’ouest, par des vergers de cerisiers, ne portant pas de fruits car surgreffés ou trop jeunes, donc non traités, puis d’une vigne.

La parcelle d’essai Témoin non traité et Référence représente un ensemble de 55 arbres sur une superficie de 1650 m². Les rangs de Van sont alternés avec des rangs de Buralat, servant de pollinisateur. Etant donné le caractère précoce de Burlat, ces rangs n’ont pas été traités contre la mouche. La zone Référence se trouve sur trois rangs de Van, à l’intérieur de la parcelle (cinq rangs en tenant compte des deux rangs de Burlat), et est encadrée à l’est et à l’ouest par les deux zones Témoin non traitées correspondant chacun à un rang de Van.

Figure 1: Plan de l’essai.
Figure 2: Environnement proche des parcelles d’essai.
entouré de deux rangs de Burlat. Au nord de cette parcelle, une parcelle de vigne ; à l’est, un terrain semé d’avoine; au sud et à l’ouest, des parcelles de cerisiers adultes traitées contre la mouche. La parcelle d’essai GF-120 se trouve au nord-ouest.

**La réalisation des traitements**

L’application de GF-120 est particulière : il s’agit d’une application localisée sur la face sud-ouest de l’arbre, sur une bande de un mètre de hauteur sur 30 cm de large. Le volume de bouillie est donc très bas: 30 l/ha. L’appareil de traitement utilisé est ici un pulvérisateur à jet projeté «pulvexper». Un temps d’application de 4,5 secondes par arbre, sous la pression de 1 bar, projette une dose de 50 ml de bouillie. La buse utilisée (Teejet 8003 VS) permet l’obtention de grosses gouttes, conseillées par la firme.

L’application de Dimezyl 40EC a été réalisée à l’aide d’un pulvérisateur à jets portés, automotrice, ou d’un atomiseur tracté sur la base de 600 à 700 l/ha.

Dans tous les cas, un contrôle, *a posteriori*, des volumes appliqués est réalisé après chaque application.

**Les observations et analyses**

Dès la fin de la chute des pétales (deuxième quinzaine d’avril), deux pièges chromatiques englués Rebell® ont été posés sur chacune des parcelles d’essai. Ces pièges sont relevés trois fois par semaine.

A la mise en place de l’essai, dix arbres ont été repérés par modalité. Ils ont été choisis de façon aléatoire, tout en évitant les effets de bordure. A la maturité phénologique de la variété, 200 fruits ont été récoltés sur chacun de ces dix arbres, préférentiellement sur la face sud-ouest de l’arbre et vers le haut de l’arbre. Chaque fruit est ouvert individuellement et observé de façon à noter ou non la présence d’une larve. Nous avons distingué trois catégories de fruits :

– les fruits sains,
– les fruits véreux avec présence d’un vers vivant ou mort,
– les fruits manifestement attaqués mais non porteur de vers.

Pour ce qui concerne le traitement au GF-120, la sensibilité de la culture et tout effet non intentionnel sur la végétation ont été observés et décrits de manière qualitative et quantitative (observations les jours précédents et suivants chaque traitement).

L’analyse des résultats consiste en l’établissement de la courbe de vol de la mouche de la cerise, et la comparaison de moyenne pour le s variables « dégâts ». Aucune analyse de variance n’est réalisée, le dispositif expérimental ne s’y prêtant pas.

**Résultats**

Les résultats sont présentés dans le tableau 3. En 2004, le GF-120 est apparu très décevant. Le taux de cerises véreuses est quasiment semblable au témoin non traité, tandis que la référence chimique présente une efficacité très bonne. L’étude plus fine du positionnement des applications de GF-120 par rapport à la courbe de vol de la mouche indique que la première intervention est trop tardive (figure 3). En effet, le premier traitement à base d’attracticide a lieu le 18 mai, soit 22 jours après la capture de la première mouche sur la zone GF-120. Ce positionnement tardif du traitement n’a pas permis de contrôler l’ensemble de la population de mouche.

En 2005, puis 2006, la protection du verger à base de GF-120 a donc débuté beaucoup plus tôt, respectivement 5 et 2 jours après la capture de la première mouche dans la zone concernée (figures 4 et 5). Les résultats d’efficacité du GF-120 en ont été nettement améliorés. En 2005, le taux de cerises véreuses dénombrées sur la zone traitée au GF-120 est
semblable à celui observé sur la zone de référence chimique ; en 2006, les résultats restent satisfaisants mais moins positifs qu’en 2005. La cadence ralentie des traitements, espacés de 10 jours et non plus de 7 jours, pourrait en être la cause.

Tableau 3: Pourcentage de fruits touchés (avec ou sans vers) selon les modalités étudiées.

<table>
<thead>
<tr>
<th></th>
<th>Vers présents</th>
<th>Vers absents</th>
<th>Total fruits touchés</th>
<th>Vers présents</th>
<th>Vers absents</th>
<th>Total fruits touchés</th>
<th>Vers présents</th>
<th>Vers absents</th>
<th>Total fruits touchés</th>
</tr>
</thead>
<tbody>
<tr>
<td>TNT</td>
<td>2,8</td>
<td>4,3</td>
<td>7,1</td>
<td>2,7</td>
<td>2,2</td>
<td>4,9</td>
<td>4,0</td>
<td>2,0</td>
<td>6,0</td>
</tr>
<tr>
<td>Dimezyl EC</td>
<td>0,1</td>
<td>0,0</td>
<td>0,1</td>
<td>0,2</td>
<td>0,3</td>
<td>0,5</td>
<td>0,1</td>
<td>0,1</td>
<td>0,2</td>
</tr>
<tr>
<td>GF-120</td>
<td>4,8</td>
<td>1,7</td>
<td>6,5</td>
<td>0,3</td>
<td>0,4</td>
<td>0,7</td>
<td>0,8</td>
<td>0,9</td>
<td>1,7</td>
</tr>
</tbody>
</table>

Figure 3: Courbe de vol de la mouche et dates d’application du GF-120 en 2004.

Figure 4: Courbe de vol de la mouche et dates d’application du GF-120 en 2005.
Figure 5: Courbe de vol de la mouche et dates d’application du GF-120 en 2006.

En 2004 et en 2006, aucun symptôme de phytotoxicité n’a été observé sur feuilles, ni sur fruits. En 2005, et ce dès la deuxième application de GF-120, nous avons observé quelques brûlures ponctuelles de 2 à 5 mm diamètre sur les feuilles dans la zone traitée. Cela dit, ramenées à la masse foliaire totale, ces brûlures sont totalement négligeables.

Discussion

Les résultats des essais d’efficacité du GF-120 dans la lutte contre Rhagoletis cerasi L. nous semblent encourageants puisque, dans des conditions d’applications correctes (positionnement et cadence des applications), le GF-120 permet d’atteindre un niveau de dégâts proche de la référence chimique, le Dimezyl 40EC.

Deux bémols doivent néanmoins être mentionnés:

1. Les essais présentés ici ont été réalisés dans des conditions de pression peu élevées, respectivement 7,1, 4,9 et 6 % de dégâts dus à la mouche. Des questions demeurent concernant l’efficacité du GF-120 dans des situations de pression plus élevées. Il conviendra de renouveler ces essais dans des zones davantage infestées par la mouche de la cerise.

2. Le nombre de traitements ainsi que la cadence nécessaire pour couvrir l’ensemble de la période de vol de la mouche sont très contraignants si on les compare à la lutte chimique larvicide qui ne nécessite, dans de nombreux cas, qu’un seul traitement, éventuellement renouvelé dans le cas de variétés tardives. Dans les zones où le vol de la mouche s’étale sur plus de 5 semaines, et dans la mesure où la firme préconise à l’heure actuelle 4 traitements maximum par an, il ne sera pas possible de proposer une couverture totale. De plus, le type d’application localisée nécessite un aménagement technique des appareils de traitement. Il ne s’agit plus de traiter une parcelle avec un atomiseur sur la base d’un volume / hectare de 700 l, mais bien de traiter par spot ou ligne à 30 l/hectare. Facilement réalisable, ce type de traitement est néanmoins nouveau pour les arboriculteurs et nécessitera un accompagnement technique.

Aujourd’hui, les filières commerciales ne tolèrent en définition aucune cerise véreuse. Le GF-120 n’offre pas une efficacité totale et parfaite et les quelques pourcents résiduels de dégâts peuvent, dans ce cadre si strict, disqualifier dès aujourd’hui ce produit.
Cela dit, dans le contexte actuel du retrait potentiel du diméthoate en agriculture conventionnelle et au sein de la filière « cerise biologique » dans laquelle aucune solution de lutte efficace n’existe à ce jour, le GF-120 dont le profil toxicologique et écotoxicologique est particulièrement favorable apparaît comme très intéressant.

Références


Bait sprays to control the European Cherry Fruit Fly \textit{Rhagoletis cerasi}

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Abstract: In 2005 and 2006 experiments to control \textit{Rhagoletis cerasi} with bait sprays were carried out in field cages with single cherry trees. The intention was to examine possible effects of different bait spray formulations on the mortality of \textit{R. cerasi} (short term tests) and fruit infestation (long term tests). Baits containing spinosad (GF-120™ Naturalyte Fruit Fly Bait and a corn by-product as bait), NeemAzal\textsuperscript{®}-T/S with azadirachtin as insecticidal component and, as insecticidal standard, α-cypermethrin were used. NeemAzal\textsuperscript{®}-T/S and α-cypermethrin were mixed in a sugar-brewers yeast solution as bait. 30 ml of bait solution were sprayed on 2 to 3 branches of each caged tree, and a defined number of cherry fruit flies was released after treatment. For short term tests bait sprays were applied and fruit flies released only once. In these experiments fruit flies were recaptured with yellow sticky Rebell\textsuperscript{®} traps. For long term tests, one bait application per week and 3 releases of \textit{R. cerasi} were realized within 4 weeks. In the short term tests the different bait spray formulations with spinosad resulted in mortalities of \textit{R. cerasi} of up to 100 %, which differed significantly from the control. In another short term test with GF-120 a significant decrease of fruit flies was observed after 3 hours with an efficacy of 79 %, which increased up to 100 % after 3 days. In long term tests fruit infestation decreased significantly with GF-120 as well as with the neem product containing bait formulation (efficacy 95 %, 84% respectively). Persistence of GF-120 was satisfying for at least 9 days, when treated cherry leaves were kept under a UV translucent, but rainproof foil.

These results indicate a high potential of bait sprays against \textit{R. cerasi}, but further investigations are required to develop a feasible strategy to control the pest.

Key words: cherry fruit fly, \textit{Rhagoletis cerasi}, bait spray, GF-120, spinosad, neem

Introduction

The European cherry fruit fly is the most important pest in cherry orchards, causing fruit damage and yield losses (Vogt, 2002; Daniel & Wyss, 2003). The use of broad spectrum insecticides with dimethoate as active substance in conventional farming is restricted, and an annual exemptional permission is required in Germany (§ 11 PflschG). In organic and integrated cherry production no effective control was possible until now. Since 2006 ‘Spruzit Neu’ (a.i.: pyrethrines and rape seed oil; W. Neudorff GmbH KG, Emmerthal, Germany) is registered against sucking and biting insects in cherries with two applications per year. Side effects of this insecticide are used against cherry fruit fly. As its persistence is rather short, this may limit the efficacy from case to case. Hence, there is an urgent need to develop alternative strategies for all, conventional, integrated and organic cherry growers, which can also include origins of infestation, like back yard cherry trees.

One possibility to control cherry fruit fly might be bait sprays. In contrast to cover sprays the per ha rate of insecticides is strongly reduced and combined with a food bait formulation.
Food bait formulations should act as phagostimulant and the higher the intake of the bait spray the better is the effect of insecticides. Main bait components up to now are proteins and sugar. Both components are necessary for adult feeding (e.g. Boller, 1971, 1984; Haisch, 1968). This method, previously using broad spectrum insecticides, is applied since years against different species of fruit flies (Roessler, 1989). In using new reduced-risk insecticides against *Rhagoletis* species in the US (e.g. Pelz et al., 2004, 2006; Yee & Chapman, 2005), good experience have been gained with the spinosad containing GF-120™ Naturalyte Fruit Fly Bait (Dow Agrosciences, Indianapolis, Indiana, USA, i.e. Burns et al., 2001, Prokopy et al., 2003). Spinosad is an insecticide, naturally derived from the actinomycete *Saccaropolyspora spinosa* (Sparks et al., 1998, Thompson et al., 2000). GF-120 Fruit Fly Bait is registered against the north American cherry fruit fly species *R. indifferens* and *R. cingulata* in the US and Canada. First experience with bait sprays against *Rhagoletis cerasi* have been published by Haniotakis et al. (1987) and Köppler et al. (2006). The azadirachtin containing neem product NeemAzal-T/S® (Trifolio-M GmbH, Lahnau, Germany) might be another naturally derived insecticidal component for bait sprays, based on extracts from the neem tree *Azadirachta indica*. Neem is known to reduce the fertility of fruit fly females (Köppler unpub.; Ilio et al., 1999). Following, fruit infestation can possibly be decreased. Beside the commercially produced GF-120 Fruit Fly Bait, other food baits are conceivable. The protein and sugar mixture, proposed by Boller (1984) could be used as food attractant. Furthermore, a corn by-product was already tested as bait for *Rhagoletis* species (Yee, 2006).

The main objective of this work was to find and evaluate bait sprays based on different food baits and insecticides against *Rhagoletis cerasi* in field cages. Thereby, the effect of bait sprays on the mortality of *R. cerasi* including efficacy rate after different periods of time, on fruit infestation as well as the persistence of the bait sprays, were the main questions.

**Material and methods**

In 2005 and 2006, the experiments on mortality of flies and fruit infestation, were carried out in field cages on cherry cultivars ‘Hedelfinger’ and ‘Kordia’ on dwarving rootstock (planted 1977 and 2002, respectively). Single trees were caged with a 3 x 3 x 3 m in size sewed gaze ‘Tuell 01’ (Brettschneider Fernreisebedarf GmbH, Munich, Germany), held by a metal water pipe frame and fixed at the ground with sand. An entrance for the cages was realized by a zipper. In each experimental trial, there were 4 replicates (2 in each on ‘Hedelfinger’ and ‘Kordia’) and 30 ml of bait sprays were applied on 2 to 3 branches of each tree using a handsprayer. To reduce fruit fly population with different bait spray formulations and concentrations, short term tests were conducted after cherry harvest. Because of a lack of cages, in most short term tests control treatments consisted in a sugar brewers yeast solution (4:1:7, control 1 & 3). Only for GF-120 in a 20 % solution GF-120 Blank was applied as control treatment (control 2). Long term tests to detect fruit infestation using bait sprays, were conducted according to the natural phenology of fruit fly population and cherry ripening. In long term tests, both control treatments, i.e. the sugar brewers yeast and the GF-120 Blank control, were included. For all tests a defined number of fruit fly males and females were released about one hour after application, originating from field collected pupae in the preceding years, which were stored in a cold room for diapause and kept at room temperature for emerging of adults. To define mortality after bait spray application in short term tests, surviving flies were recaptured with yellow sticky Rebell® traps (Andermatt Biocontrol AG, Grossdietwil, Switzerland). To avoid starvation of the released flies, two strips with brewers yeast and sugar (1:4 mixed with water and dried again on filter strips), were fixed on caged trees.
**Short term tests**

In short term tests the bait formulations GF-120 Fruit Fly Bait, which contains 0.02 % spinosad (diluted to 1, 5, 10 and 20 % by volume), the corn by-product mixed with 0.02 % spinosad and diluted to 20 % by volume, the sugar-brewers yeast water solution (4:1:7) mixed with NeemAzal®-T/S (5, 10 and 20 % by volume) and for comparing reasons, the sugar-brewers yeast water solution (4:1:7) mixed with the pyrethroid α-cypermethrin (0.5 and 1.0 % by volume) were used. In all short term test, one application per cage was made. 10 or 15 *R. cerasi* males and 15 or 20 *R. cerasi* females, respectively, depending on available number of cherry fruit flies, were released into the cages after drying of bait sprays. To test different bait spray formulations, Rebell® traps were placed in the cages after 24 hours. In short term tests, defining the efficacy rate after time, only GF-120 in the 20 % solution was used and Rebell® traps were placed after 3, 6, 24 hours, 2 and 3 days.

**Long term tests**

To reduce cherry infestation in long term tests, bait sprays were applied once per week from the end of May till the end of June. Only the third application was repeated the next day after a heavy rain. In total there were 5 applications. The time of release of cherry fruit flies was adapted to the flight peaks of the natural cherry fruit fly population, detected by Rebell® traps distributed in the cherry orchard for monitoring reasons. According to this, there were 3 releases of flies, which took place on the same day as the first, second and third bait spray application after drying of bait droplets. At the beginning of July, all cherries per cage were harvested and fruit infestation was determined by manual opening of the fruits. With that method, also symptoms of infestations could be counted, when instars had already left the fruits.

**Persistence of bait sprays**

UV persistence of bait sprays is an important factor to reduce the number of applications. To examine the persistence, GF-120 Fruit Fly Bait and GF-120 Blank as the control treatment, both in a 20 % solution, were applied on cherry foliage of cut branches, which were positioned underneath a UV translucent, but rainproof foil (Folien-Vertriebs GmbH, Dernbach, Germany). Leaves for tests with cherry fruit flies were cut at day 0, 2, 5, 7, 9 and 13, respectively, and placed in small glass cages (diameter 9.5 cm, height 3.0 cm) together with water and food supply (sugar and brewer’s yeast) for the flies to avoid possible starvation. In each cage 3 *R. cerasi* males and 3 females, respectively, were released and behaviour of the flies was observed hourly between 8 a.m. and 6 p.m. for 48 hours. A bait effect was concluded, when flies were dead or weak (i.e. lying on their back side, still moving their legs).

**Statistical analyses**

Statistical analysis was conducted with SPSS 10.0 for Windows (SPSS Incorporation, USA).

**Results and discussion**

**Short term tests**

In short term tests, all bait spray treatments, except the sugar brewer’s yeast solution with 10 and 20 % NeemAzal®-T/S differed significantly from the control and caused high mortality rates (Fig. 1; U-test 0.01 < P < 0.05, P < 0.01). With both bait sprays, containing spinosad (diluted to 20 % by volume, consequently 0.004 % spinosad in total), GF-120 and the corn by-product as bait resulted in a total mortality of flies and efficacies of 100 %. These results indicate a high susceptibility of *Rhagoletis cerasi* to bait spray formulations containing only 0.004 % spinosad, applied on cherry tree foliage in field cages. With regard to GF-120, this is the lowest amount, recommended in GF-120™ Naturallyte Fruit Fly Bait Technical Bulletin (Anonymous, 2002), were a dilution of 1 : 1.5 - 5.0 is proposed. Following, higher dilutions...
mean lower cost for growers. Additionally, also the second bait formulation with the same amount of spinosad used in our experiments, can cause equal mortality rates. Spinosad in another protein bait formulation was also tested in Stark et al., 2004. This could open a higher flexibility in application and registration of bait spray formulations in Germany.

GF-120 in lower concentrations only led to efficacies of 63 and 85 %. Even the pyrethroid α-cypermethrin in a sugar brewers yeast solution only reached efficacies between 92 and 94 %. Efficacies of the neem bait were low (between 34 and 42 %) and did not represent a good bait and kill effect. Following, neem did not cause a high and quick mortality of cherry fruit flies in this study, after they fed on neem containing bait. Moreover, higher concentrations of neem as used in our experiment could have a deterrent effect to flies, because no significant increase of mortality with higher neem concentrations could be found. In contrast, Illo et al., 1999 described a reduced longevity of *Ceratitis capitata*, after they had fed on a neem containing diet.

Due to temporal differences between the different short term tests, there were several controls. These control treatments differ significantly for control 1 and 3 (ANOVA; Scheffé 0.01 < P < 0.05). This can be caused by variations in the age of used flies, because of delaying of experiments caused by rain periods. Furthermore, weather conditions varied between the test series, which also can influence constitution of the flies.

![Figure 1](image.png)

Figure 1. Short term test to compare different baits and insecticides in different concentrations: Recapture of *R. cerasi* (%); because of different dates for these tests, 3 controls were necessary: C1 = brewers yeast + sugar control for all black bars, C2 = GF-120 Blank control for GF-120 20 %, C3 = brewers yeast + sugar control for C-S 20 %; GF = GF-120 Fruit Fly Bait, YS-N = brewers yeast + sugar + NeemAzal®-T/S, YS-C = brewers yeast + sugar + α-cypermethrin, C-S = corn by-product + spinosad, * U-test 0.01 < P < 0.05, ** U-test P < 0.01; indication of standard deviation.

In another short term trial to test the efficacy rate of GF-120 dependent on time, significantly higher mortalities (U-test 0.01 < P < 0.05) than in the control were detected already 3 hours after treatment, with an efficacy of 79 %. The later the Rebell® traps were placed in the cages, the higher was the mortality of flies (Fig. 2), reaching efficacies up to 100 %. But even in the control cages, mortality increased after longer periods of time. This mortality could be caused by other factors, e.g. natural enemies like spiders, decreasing fitness and aging of flies with increasing time. Following, though only single *R. cerasi* specimens were recaptured in the GF-120 treatment after two days, the efficacy decreased at this date (68 %).
Long term test
The application of GF-120 in the 20 % solution (0.004 % spinosad) and the neem bait resulted in a significant reduction of fruit infestation (Fig. 3; ANOVA, Scheffé 0.01 < p < 0.05 and P < 0.01). Efficacies are 95 % and 84 %, respectively. Only with GF-120 in the 5 % solution, no significant result was achieved (efficacy 75 %). The results caused by the spinosad containing bait confirm those from the short term tests. Spinosad in a bait formulation causes a high mortality of flies and following less eggs are layed into cherries. Despite of surviving of flies feeding on neem containing bait in the short term tests, the infestation rate of fruits decreased significantly, too. This is a confirmation of results in the lab, where neem containing bait decreases fertility of R. cerasi females (Köppler unpup., Ilio et al., 1999). But still, the infestation rate was too high and above the official threshold for fruit infestation of 2 %. Only with GF-120 in the 20 % solution that threshold was not exceeded.

As well as the results of the short term experiments, these results indicate a high susceptibility of R. cerasi to bait sprays. But, despite of releasing flies into the cages according to natural population flight peaks and right ripening status of cherries for egg laying, these are still model type experiments. Field experiments under practical conditions are needed to define bait spray effects on natural population and fruit infestation.

Persistence of bait sprays
Fig. 4 and 5 show the progress of mortality or weakness of flies within 48 hours, according to treatment of cherry leaves with GF-120 Blank as control or GF-120. In the control a high percentage of more than 80 % of flies survived the experiment in most cases (Fig. 4). Only the experiment with two days old treated leaves resulted in higher mortalities, but still leading to a significant difference to GF-120 in the same trial (U-test P < 0.05). As shown in Fig. 5, almost all flies in contact with leaves treated with GF-120 died within 48 hours. 0, 2, 5 and 9 days old with GF-120 treated leaves caused a mortality of flies higher than or equal 50 %. Only with 7 days old treated leaves, flies survived slightly longer, but died at least within 48 hours. In the case of the 13 days old treated leaves, about 40 % of flies were still alive after 48 hours. Nevertheless, all treatments with GF-120 caused a significantly higher mortality as the control, except at day 13 after 12 hours (U-test P < 0.05).
Figure 3. Long term test to reduce fruit infestation (%); ANOVA, *Scheffé 0.01 < p < 0.05, **Scheffé P < 0.01; indication of standard deviation.

Figure 4. Persistence of GF-120 Blank control (20 % solution): Fit flies after different periods of time.

Figure 5. Persistence of GF-120 Fruit Fly Bait (20 % solution): Fit flies after different periods of time.
These results show a good persistence and high bait and kill effects of GF-120 for at least 9 days without rain. According to the GF-120 Fruit Fly Bait Technical Bulletin (Anonymous, 2002), control of flies can be provided for 10 or more days. Appropriate to the middle European climatic conditions and phenology of cherries and cherry fruit fly, this means about 3 to 4 sprayings to avoid fruit infestation. In contrast, a significant difference in attractiveness of GF-120 bait sprays were found between 2 and 24 hours old sprayings for melon fly (Revis et al., 2004). Furthermore, rainfastness was not put into consideration in this study. All used bait spray formulations, including GF-120 Fruit Fly Bait can be washed off during dusty or rainy conditions (Anonymous, 2002).

Acknowledgements

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Evaluation of some insecticides for the control of the cherry fruit fly 
(*Rhagoletis cerasi*) in Integrated Production

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**Abstract:** The cherry is a typical production of the Emilia-Romagna Region and, in particular, of the “typical growing area of Vignola” where it represents an important source of income for local producers. The cherry fruit fly is the main pest for this crop; over the last few years there has been an increase of this parasite that is currently widespread in all areas of production. Presently the control of the cherry fruit fly in the Integrated Production Management of the Emilia-Romagna Region involves the use of Dimethoate which have a toxicological profile that present risk factors for both men and the environment. This product is classified as a harmful (Xn), therefore, a license is necessary. However, over the last few years, Dimethoate-based products, have become available on the market, classified as irritant (Xi) or “Non-classified”, in which “green” solvents (fatty acid ester-based) are used. These products have replaced hydrocarbon-based products (such as xilene, nafta) commonly used in commercial products. In this way there has been an increase of Dimethoate-based products which are less toxic for men and the possibility of buying them without a license. This aspect is much appreciated among producers in Vignola, where there is elevated average age for producers and where there are numerous small part-time family-run farms. Since solvents can also influence the efficacy of products it has been necessary to carry out specific trials to evaluate the behaviour of these new products. For the same reason, the efficacy of Fosmet has also been evaluated. Fosmet is a “Non-classified” product with safety interval, which over the next few years should change from 30 to 14 days and be less than that of Dimethoate (20 days). This work was carried out in a cherry farm situated in the hills with a high cherry fruit fly population. The results of this two-year study showed good performance of this new products in tests, demonstrating an efficacy comparable to than of “harmful” Dimethoate.

**Key words:** cherry fruit fly, integrated control, Dimethoate, green solvent

**Introduction**

The cherry is a typical production of the Emilia-Romagna Region and, in particular, of the “typical growing area of Vignola” where it represents an important source of income for local producers.

The cherry fruit fly is the main pest for this crop; over the last few years there has been an increase of this parasite that is currently widespread in all areas of production. The population level is especially high in hilly zones.

Presently the control of the cherry fruit fly in the Integrated Production Management of the Emilia-Romagna Region involves the use of Dimethoate which have a toxicological profile that present risk factors for both men and the environment. In particular Dimethoate, is classified as a harmful product (Xn), therefore, a license is necessary.

However, over the last few years, Dimethoate-based products, have become available on the market, classified as irritant (Xi) or “Non-classified”, in which “green” solvents (fatty
acid ester-based) are used. These products have replaced hydrocarbon-based products (such as xilene, nafta) commonly used in commercial products.

In this way there has been an increase of Dimethoate-based products which are less toxic for men and the possibility of buying them without a license. This aspect is much appreciated among producers in Vignola, where there is elevated average age for producers and where there are numerous small part-time family-run farms. Since solvents can also influence the efficacy of products it has been necessary to carry out specific trials to evaluate the behaviour of these new products. For the same reason, the efficacy of Fosmet has also been evaluated. Fosmet is a “Non–classified” product with safety interval, which over the next few years should change from 30 to 14 days and be less than that of Dimethoate (20 days).

**Material and methods**

In two-year experimental trials 2005/06, we carried out in a farm in the hilly areas of Modena province with a high fly population.

**Study plan 2005**

The trial location was in Pavullo, Modena province, Emilia-Romagna region. One treatment was performed on 9th June, when the cherry was in the colour-change phase. The trial products were Rogor 40 (reference product), two Dimethoate-based products, Gardius and Rogor SL, irritant with green solvents and Fosmet. Cultivar was Durone della Marca, late ripening. The *Rhagoletis cerasi* flight was monitored by yellow chromotropic traps. The trial design was blocks side-by-side, with 4 replicates. The results were evaluated on 200 fruit/replicate (800 fruit/treatment). The results were elaborated statistically with analysis of variance on data transformed according to LSD formula.

**Trial 1 – 2005**

<table>
<thead>
<tr>
<th>Number</th>
<th>Treatments</th>
<th>active ingredient</th>
<th>% a.i.</th>
<th>toxic class</th>
<th>Solvent</th>
<th>gr/hl</th>
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<td>1</td>
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<td>DBE*</td>
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<td>2</td>
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<td>Dimethoate</td>
<td>19</td>
<td>Xi</td>
<td>DBE*</td>
<td>100</td>
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<td>Rogor 40 L50</td>
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<td>Xn</td>
<td>hydrocarbon**</td>
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<tr>
<td>4</td>
<td>Imidan Ec</td>
<td>Fosmet</td>
<td>17,7</td>
<td>Ne</td>
<td>DBE*</td>
<td>250</td>
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<tr>
<td>5</td>
<td>Control</td>
<td></td>
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</tbody>
</table>

* green solvents fatty acid ester-based

**Study plan 2006**

The trial location was in Pavullo, Modena province, Emilia-Romagna region. One treatment was performed on 14th June, when the cherry was in the colour-change phase. The trial products were Rogor 40 (reference product) and one Dimetocate-based product, Rogatox Ec, “Non-classified” with green solvents and Fosmet. Cultivar was Durone della Marca, late ripening. The flight of *Rhagoletis cerasi* was monitored by yellow chromotropic traps. The trial design was blocks side-by-side, with 4 replicates. The results were evaluated on 200 fruit/replicate (800 fruit/treatment). The results were elaborated statistically with analysis of variance on data transformed according to LSD formula.
Trial 2 – 2006

<table>
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<th>toxic class</th>
<th>Solvent</th>
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<tr>
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<td>Fosmet</td>
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<td>DBE*</td>
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<tr>
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<td>Rogatox Ec</td>
<td>Dimethoate</td>
<td>24</td>
<td>NC</td>
<td>DBE*</td>
<td>75</td>
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<tr>
<td>3</td>
<td>Rogor 40 L50</td>
<td>Dimethoate</td>
<td>38</td>
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<td>hydrocarbon**</td>
<td>50</td>
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<tr>
<td>4</td>
<td>Control</td>
<td>-</td>
<td></td>
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</tr>
</tbody>
</table>

* green solvents fatty acid ester-based
** Hydocarbon-based products (xilene, nafta)

Results and discussion

Trial 1 – 2005
The cherry-fruit fly flight was monitored with yellow chromotropic traps (fig. 1). In 2005 we observed a reduced flight of the cherry-fruit fly, with a maximum of 12 adults for every trap (1st June). The results show a good level of efficacy of the trial products (tab.1). These products are not statistically diverse from our reference product Rogor 40 L50. There is a significant difference with respect to the control. However, this year saw relatively little fly damage (9.6% in the control).

![Figure 1. Rhagoletis cerasi flight 2005](image-url)
Table 1. Results 2005

<table>
<thead>
<tr>
<th>Number</th>
<th>Treatments</th>
<th>Damage %</th>
<th>LSD**</th>
<th>Efficacy Abbott (%)</th>
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<td>Rogor 40 L50</td>
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<td>B</td>
<td>86.3</td>
</tr>
<tr>
<td>4</td>
<td>Imidan Ec 0.6</td>
<td>93.7</td>
<td>B</td>
<td>93.7</td>
</tr>
<tr>
<td>5</td>
<td>Control 9.6</td>
<td>A</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Lsd test (** P<0.01. Harvest cultivar Durone della Marca 4/7

Trail 2 – 2006

In 2006 the trial was carried out in the same farm and another “non-classified” Dimethoate-based product was evaluated, as well as Fosmet. In 2006 the cherry-fruit fly flight (fig. 2) was very elevated and a maximum of 80 insects per trap was registered (in 2005 the maximum level was 12 per trap). However, due to high population levels and the elevated sensitivity of the variety (Durone della Marca) the percentage levels of damage are present on the control (76.2%). This late-ripening variety is more prone to attack from the cherry-fruit fly. Unlike other varieties where eggs are predominantly laid during the colour-change phase, Durone

![Rhagoletis cerasi flight 2006](image1.png)

Figure 2. *Rhagoletis cerasi* flight 2006

Table 2. Results 2006

<table>
<thead>
<tr>
<th>Number</th>
<th>Treatments</th>
<th>Damage %</th>
<th>LSD**</th>
<th>Efficacy Abbott (%)</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>Control 76.2</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Rogatox Ec 17.8</td>
<td>b</td>
<td></td>
<td>76</td>
</tr>
<tr>
<td>3</td>
<td>Imidan EC 16.7</td>
<td>b</td>
<td></td>
<td>78</td>
</tr>
<tr>
<td>4</td>
<td>Rogor 40 L 16.5</td>
<td>b</td>
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<td>78</td>
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</tbody>
</table>

Lsd test (** P<0.01. Harvest cultivar Durone della Marca 7/7
della Marca, of the two-colour variety (white and red) undergoes egg-laying up to harvesting. The efficacy of new products – Rogatox and Imidan Ec – is not significant in respect to that of reference products. Results and efficacy are shown in table n. 2.

**Conclusion**

Our two-year trial has shown that:
- new Dimethoate-based products with “green” solvents demonstrate efficacy levels comparable to that of “harmful” Dimethoate;
- Fosmet provides positive results and could be included in cherry-fruit fly prevention programs as a non-classified product with a safety interval (14 days) lower than Dimethoate (20 days).

Further studies are necessary to:
- confirm the results of the two-year trial 2005/06;
- assess new products with a “low environmental impact”, especially important for a crop in which there are few days between fly treatment and eventual consumption;
- direct new research towards the use of Spinosad (bait). This is a natural substance, obtained from the fermentation of *Saccharopolyspora spinosa* bacteria, already used in integrated prevention programs of the most important fruit species.

**References**


Area-wide mass trapping to control *Ceratitis capitata* (Wied.) on stone fruits in Girona, NE of Spain

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Abstract: A project involving Mediterranean fruit fly (*Ceratitis capitata* (Wied.) (=MFF) (Diptera: Tephritidae) control was carried out in 2005 and 2006 in stone fruit area of Girona by using a mass trapping method in accordance with a compulsory regional order to prevent fruit damage by this pest which included economic aids for the traps and the attractants the fruit growers needed. The aim was to control the MFF using a mass trapping method instead of chemicals. The strategy used was to detect the first adult MFF activity using a network of control points and, as soon as the pest occurrence was verified, to install a mass trapping system in the orchards to compete at an advantage with the stone fruits there. The mass trapping system used consisted of placing Maxitrap® model (Probodelt) traps, with Ferag CC D TM® lures (SEDQ) and DDVP insecticide inside, in doses of 50 per ha. The lures consisted of 3 membrane dispensers of trimethylamine, ammonium acetate and diaminoalkane. Once the harvest was completed, the fruit remaining in the fields was mechanically ground. In trial conditions during the two years, the project to control the MFF had very good results. Only slight damage was found at harvest in a few peach orchards (< 0.7 % of the fruits) and chemical insecticide sprayings not needed throughout the ripening process of the fruits.

Keywords: Mediterranean fruit fly, *Ceratitis capitata*, mass trapping, control.

Introduction

Mediterranean fruit fly (MFF) (*Ceratitis capitata* (Wied.) (Diptera: Tephritidae) is one of more poliphagous, detrimental and extended fruit trees pest. In some fruit growing areas, MFF’s population presents considerable fluctuations throughout the years and, although several authors have tried to explain this phenomena being based on temperature, on humidity or on the availability of guests (Bateman, 1972; Harris, 1993; Celedonio-Hurtado, 1995), a rule that could be applied in a general way, in all areas where the insect’s population levels vary considerably from one year to the next one, has not yet been found. In some cases, like in the North of Greece and Israel (Papadopoulos *et al.*, 1996; Israely *et al.*, 1997), it has been demonstrated that the insect’s capacity to bear with winter temperatures determinates the development of next year’s population; suggesting also, that its genetic adaptability makes it possible to expand to regions where traditionally it was not a serious problem.

In the NE of Spain, a remarkable increase of its populations has taken place since the year 2000 onwards (particularly in 2001 and 2003), which caused serious damages on fruits of late summer and autumn peach and apple cultivars, making the adoption of defence methods essential to avoid fruit damages. In most cases, insecticides near harvest are applied, which entails a great risk of presence of pesticides residues on the fruits at harvest, and also may have an important negative effect on the orchards’ auxiliary fauna. Besides, the
application of these insecticides does not guarantee, in most of the cases, that fruit damages will be avoided.

Since the beginning of this decade, IRTA- Agricultural Experimental Station Mas Badia, together with the Plant Protection Service of the Agriculture Department of the Generalitat of Catalonia, are carrying out field trials with fly traps and attractants, with the objective to find the best system to monitor, with the highest precision possible, the MFF’s populations of the area. In parallel, various systems of mass trapping are being tested to evaluate the efficiency of this method, in order to be used as an alternative system to chemical approaches (Escudero et al., 2005). This system is based on the installation of a high number of fly traps per unit of surface with food attractants and a volatile insecticide, aiming to capture the highest number possible of pest adults. The new solid food attractants in membrane diffusers have improved the application of this method making it easier and more practical.

Several studies have proved the efficiency of the mass trapping method against MMF (Alemany et al., 2004; Batllori et al., 2005; Epsky & Heat, 1998; Heat et al., 1996, 1997; Ros & Castillo, 1994; Ros et al., 1999; Satre et al., 1999). Other studies (Batllori et al., 2005; Escudero et al., 2005) demonstrate that for an area such the one under study, the fruit production can be protected using this system without the need to apply any chemical product against this pest and, that only in late cultivars in years with unusual high population, fruits have to be protected with additional insecticides. With this approach, both the environmental impact and the possibility to find residues on the fruits are reduced.

The fruit production area of Girona province (NE of Spain) is structured in big companies and cooperatives of production, from which the majority of the fruit producers apply the Integrated Fruit Production. For that reason, and taking into account the previous experiences with the mass trapping method, this project was implemented in a large geographic area. The present project was based on both, the Real Decree 461/2004 and the rule ARP/295 of 2004 (D.O.G.C. of 30 of August) of the Generalitat of Catalonia, in which the adoption of prevention and fighting measures against the MFF to avoid fruit damages were declared of public utility all over Spain.

The objective of the project was to replace the insecticide treatments against MFF with the mass trapping method in the fruit stone growing area of Girona.

Materials and methods

The fruit growers with peach orchards located in fruit stone production area of Girona (‘Alt Empordà’ and ‘Baix Empordà’ counties) participated in the project. The strategy used consisted firstly, on detecting the beginning of the MFF adults activity by means of a monitoring trap network distributed over the insect's performance area. Secondly, the mass trapping method was applied in all orchards (except the harvested ones) once the presence of the insect was confirmed. The general characteristics of the project are shown in the Table 1.

Monitoring traps were installed in all stone fruit orchards at the beginning of June, in order to detect of the beginning of the activity of the adults as well as to monitor of the pest. They were composed by Probodelt® (Maxitrap® model) traps with Trypack® attractants (Suterra) in 2005, whereas in 2006 the attractants were Ferag CC D TM® (SEDQ); in both years insecticide DDVP were used. The attractants were composed by three membrane dispensers of ‘Trimethylamine’, ‘Ammonium acetate’ and ‘Putrescina’ in the Trypack® and, ‘Trimethylamine’, ‘Ammonium acetate’ and ‘Diaminoalkane’, in the case of Ferag CC D TM®.
Table 1 General characteristics of the application of mass trapping method for the control of MFF in 2005 and 2006.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total acreage (ha)</th>
<th>Nº Orchards</th>
<th>Monitoring Traps</th>
<th>Total number of traps</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>300.8</td>
<td>224</td>
<td>231</td>
<td>15045</td>
</tr>
<tr>
<td>2006</td>
<td>250.1</td>
<td>184</td>
<td>205</td>
<td>12424</td>
</tr>
</tbody>
</table>

The same type of traps Probodelt® (Maxitrap®) was utilized for the mass trapping method, with attractants (Ferag CC D TM®) plus insecticide (DDVP), both presenting 120 days of life length. Traps were homogeneously distributed in the orchard at 50 traps per ha (each one covering 200 m2). Traps were not removed until 15 days after harvest (minimum), in order to avoid the emigration of MFF to fruits of later varieties. On the other hand, growers were obliged to destroy the non-commercial fruits left in the parcels.

The project was evaluated at orchard level (although it covered an extensive geographic area). The evaluation parameters were the following:

a) Population dynamics of MMF. One monitoring trap per orchard was evaluated weekly. The technical advisers of the producing companies were weekly informed of the catches obtained.

b) Determination of the pest pressure and the need for insecticides application. The project recommended additional chemical sprayings when more than 5 females per trap and day were captured.

c) Effectiveness of the method. Evaluations of fruit damages caused by MFF were carried out at harvest in 5% of the project orchards. In each orchard, 10 fruits per tree and 10 fruits of the ground (around each of these trees) were examined on 50 trees per ha. The data was analysed with S.A.S software. Tridimensional charts were done for damage distribution and trap catches.

d) Destruction of non-commercial fruits. The compulsory regulation on prevention and fighting against MMF obliges all producers to destroy, just after harvest, all non-commercial fruits found on the trees and on the ground (Rule ARP/295 of DOGC nº 4439).

**Processing data**

All monitoring traps were georeferenced in order to monitor the population distribution over the project area using GIS (Geographic Information System). Tridimensional charts of evaluations of fruit damages and trap catches were developed with S.A.S.

**Results and discussion**

**Population dynamics of MMF**

The monitoring traps were checked from the first week of June until the end of September. The first adult was captured on the 22nd of June in 2005, and on the 26 of June in 2006. Fruit

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1 The total area of stone fruits trees of Girona decreased considerably in 2006 due to low fruit prices of 2005.
growers installed the traps of the mass trapping during the first and second week of July 2005 and 2006, respectively.

The pest population level was based on the catches obtained in the monitoring traps during the period between the date of the first capture and the harvest of the latest varieties. In 2005, the population level of MFF adults was low, it increased slowly since the middle of August and it reached the maximum of 0.5 adults/trap/day in September, when all stone fruits had already been harvested (Graphic 1).

![Figure 1. Spatial distribution of some peach orchards included in the compulsory campaign against MMF, “Baix Empordà”, 2005.](image1)

![Figure 2. Population dynamics of MFF adults based on the averages values of 224 monitoring traps, Girona, 2005.](image2)
The population level in 2006 was considerable higher in comparison with 2005. Since the end of July the population continuously increased and showed a great rise during the month of September. Throughout the same period, the maximum of catches was 5 times higher than in 2005 (Graphic 2). Once peach harvest ended, the population of MMF increased up to a maximum of 18.8 adults/trap/day*. In the case of late varieties of apple trees, the maximum was 51.7 adults/trap/day during the first two weeks of October.

Figure 3. Population dynamics of MFF adults based on the averages values of 205 monitoring traps, Girona, 2006.

The date of the first catches agree with those reported in studies done at the Northern limit of the distribution area of *C. capitata* (Katsoyanos *et al.*, 1998; Papadopoulos *et al.*, 2001; Israely *et al.*, 1997), and on similar host plants. According to the same authors, the population dynamics are also similar, showing an increase from September onwards, a maximum in October and a progressive reduction until the end of December.

It is stated again the influence that temperature has on the development of the population of MMF, aspect already well-known of its biology. Thus, 2006 was warmer and had higher populations in comparison with 2005. In 2006 the average temperature from January to November was 16,5ºC, whereas in 2005 was 15, 3ºC for the same period.

**Determination of the pest pressure**

In none of the two years of the project the threshold of 5 females per trap and day was reached, therefore there was no need for any treatment with insecticides. Nevertheless, in the near by orchards in which the mass trapping method was not used, the pest population was higher. A comparison was done between the group of orchards included in the project and 15 other orchards of the same area in which chemicals were applied. It could be observed that those with conventional applications had a much higher average of catches per trap, where they increased from 24 to 70 from the middle of August to the middle of September, whereas, in the mass trapping orchards the average number of catches went from 8 to 12 during the same period (Figure 3).

In other studies on mass trapping carried out on single parcels (Alemany *et al.*, 2004), it was not possible to determinate if the reduction of the population was caused by the mass  

* Average value of 11 orchards in which the mass trapping traps were kept.
trapping method itself. The results of the present study indicate that when the mass trapping method is applied over an extensive geographic area, the increase of population generally observed during the season is lower than when the chemical products are applied.

Figure 4. Average accumulated catches per trap in the peach orchards of the project (191) compared with orchards treated with insecticides (15), Girona 2006.

**Evaluation of crop damages**

Table 2 shows that in 2005 no fruit damages were found in any of the 20 orchards evaluated from the 8th of August to the 9th of September. It can also be pointed out that only in one of the orchards some damages were seen on fruits found on the ground. Such damages reached 0.5% in the middle of September. None of the peach plantations required insecticide sprayings against MFF.

**Table 2. Results of pre-harvest fruit evaluation in 2005.**

<table>
<thead>
<tr>
<th>Period of Time</th>
<th>Nº Orchards</th>
<th>Cultivar</th>
<th>% Damaged Fruits of the Tree</th>
<th>% Damaged Fruits on Earth</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 – 12/08/05</td>
<td>2</td>
<td>Summer Lady</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>16 – 19/08/05</td>
<td>6</td>
<td>O’henry</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>22 – 26/08/05</td>
<td>1</td>
<td>Maria Delizia</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>29/8 – 2/09/05</td>
<td>2</td>
<td>Everts</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>5 – 9/09/05</td>
<td>4</td>
<td>Gladys®</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Belletardie®</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Miraflors</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Caldesi 2020 (Sept. Queen)</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>12 – 16/09/05</td>
<td>1</td>
<td>Fairtime</td>
<td>0.00</td>
<td>0.41</td>
</tr>
</tbody>
</table>
In 2006, both the pest population and fruit damage in standard orchards were higher than in 2005 (Figures 1 and 2). In spite of this, in 2006 the number of orchards with fruit damages was low and the percentage of damages was never higher than 0.7% (Table 3). In this year none of these orchards required any treatment with insecticides against MFF.

Table 3. Results of pre-harvest fruit evaluation in 2006.

<table>
<thead>
<tr>
<th>Date</th>
<th>Nº Orchards</th>
<th>Cultivar</th>
<th>% Damaged Fruits of the Tree</th>
<th>% Damaged Fruits on Earth</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 Jul</td>
<td>2</td>
<td>Summer Rich</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>17 Jul</td>
<td>1</td>
<td>Elegant Lady</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>28 Jul</td>
<td>1</td>
<td>Summer Sweet</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 Aug</td>
<td>1</td>
<td>Summer Lady</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Summer Lady</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>18 Aug</td>
<td>2</td>
<td>Merril O’henry</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Merril O’henry</td>
<td>0.29</td>
<td>0.34</td>
</tr>
<tr>
<td>21 Aug</td>
<td>1</td>
<td>Merril O’henry</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>21 Aug</td>
<td>1</td>
<td>Merril O’henry</td>
<td>0.69</td>
<td>0.38</td>
</tr>
<tr>
<td>6 Sept</td>
<td>1</td>
<td>Merril O’henry</td>
<td>0.69</td>
<td>0.38</td>
</tr>
</tbody>
</table>

The spatial distribution of the captures and the fruit damages for an orchard with low number of catches and another with high number of catches, shows the efficiency of the mass trapping method, since no fruit damages were found in the part of the orchard where more than 50 catches per trap were captured. On the other hand, the tridimensional graphics made possible to observe the irregular distribution of the MFF within the orchards, and the little correspondence between the point where the adults were captured and the level of fruit damage around such point (Figure 4). This fact had already been observed in the study conducted by Alemany et al., 2004, in a citrus orchard in the island of Mallorca, in which it is highlighted that a greater number of insects were found at the edge of the orchards and therefore it was advised to reinforce the control at the perimeter to achieve a better protection.

The results from 2005 and 2006 indicate that the mass trapping method utilized in the compulsory campaign offered an excellent efficiency to control the MFF, making unnecessary the application of insecticides. Fruit growers felt confident with the good results of the employed method and this made possible to expand its application to other fruit species, which is a clear improvement for the Integrated Fruit Production.

**Grinding of non commercial fruits**

At the end of harvest, producers threw the remaining fruits of all cultivars to the ground and grinded them with a crushing machine. The Plant Protection Service carried out periodic inspections to verify the fulfilment of this compulsory rule. This practice is of extreme importance to decrease the pest populations remaining in the orchards because it could emigrate to neighbouring ones. A study carried out in Girona demonstrated that the development of adults could be reduced on 98% (not published).
Conclusions

The MFF populations were low in 2005 and moderately high in 2006.

The MFF compulsory fighting campaign had a clear influence on the decrease of the pest population in the area.

The compulsory fighting programme against MFF, applied in all stone fruits orchards of Girona, based on the early installation of the mass trapping method and the destruction of the non commercial fruits on the field, offered good results during the two years of the application of the project. Fruit damages were, in all cases, lower than 1% at harvest and it was possible to do without applying any insecticides during the fruit ripening.

Acknowledgements

To all companies, producers and technical advisers of Girona who participated in the project.
References


BOE (Boletín Oficial del Estado) nº 79 del 1 de abril del 2004, Real Decreto 461/2004, de 18 de marzo, por el que se establece el programa nacional de control de la mosca mediterránea de la fruta: 13793-13794.


DOGC (Diari Oficial de la Generalitat de Cataluña) Nº 4207. ARP/295/2004, en la que se establecieron medidas obligatorias de prevención y lucha contra la mosca mediterránea de la fruta (Ceratitis capitata Wiedemann).


Ros, J.P.; Castillo, E.; Wong, E.; Olivero, J. 2002: Mejora de los mosqueros, atrayentes y sistemas de retención contra la mosca mediterránea de la fruta Ceratitis capitata Wied.


Potential of ground arthropods as predators of larvae and pupae of fruit flies (Diptera : Tephritidae)

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Abstract: In fruit production, several pests of great economic importance are difficult to control by conventional pesticide applications. Moreover, the revision in registration of plant protection products has had little success, in particular for fruit flies Bactrocera oleae (Gmelin), Rhagoletis cerasi (L.) and Ceratitis capitata (Wiedemann). These pests have a very long life stage on the ground, during which predation by generalist biocontrol agents is high. Here we present a study on the food preferences of Carabidae and Staphylinidae species largely present in stone fruit orchards in South-West of France, as well as first observations on in situ fly pupae consumption. The best biocontrol agents of fruit fly populations seem to be Harpalus affinis (Schrank) and Harpalus distinguendus (Duftschmid) in spring, and Calathus fuscipes (Goeze), Pseudophonus rufipes (De Geer) and Ocypus olens (Müller) in autumn.

Key words: generalist biocontrol agent, Carabidae, Staphylinidae, Bactrocera oleae, Rhagoletis cerasi, Ceratitis capitata, Tephritidae

Résumé: En arboriculture fruitière, plusieurs ravageurs de grande importance économique sont difficiles à contrôler par les moyens de lutte conventionnels. De plus, la révision des homologations de produits phytosanitaires conduit à des impasses, notamment pour les mouches des fruits Bactrocera oleae (Gmelin), Rhagoletis cerasi (L.) et Ceratitis capitata (Wiedemann). Ces ravageurs ont un stade de développement au sol très long, durant lequel la prédation par des auxiliaires généralistes peut être importante. Nous présentons les résultats en laboratoire sur les préférences alimentaires des espèces de Carabidae et Staphylinidae largement présentes dans les vergers de fruits à noyau du Sud-Est de la France, ainsi que les premières observations sur la consommation in situ de pupes de mouches. Les espèces Harpalus affinis (Schrank) et Harpalus distinguendus (Duftschmid) au printemps, Calathus fuscipes (Goèze), Pseudophonus rufipes (De Geer) et Ocypus olens (Müller) à l’automne, semblent les plus aptes à contrôler les populations de mouches des fruits.

Mots-clés : auxiliaires généralistes, Carabidae, Staphylinidae, Bactrocera oleae, Rhagoletis cerasi, Ceratitis capitata, Tephritidae

Introduction

Les mouches des fruits sont des diptères appartenant à la famille des Tephritidae. Cette famille se caractérise par des individus aux ailes marbrées et à l’oviscape en forme de cône aplati. Elle comprend quelques uns des ravageurs les plus destructeurs de culture du monde ; par exemple, la mouche méditerranéenne des fruits (Ceratitis capitata), la mouche mexicaine des fruits (Anastrepha ludens), la mouche de l'olive (Bactrocera oleae) et la mouche de la pomme (Rhagoletis pomonella).

La lutte contre ce type de ravageur est difficile notamment parce que :
– Un nombre réduit d'adultes peut être responsable d'un grand nombre de fruits contaminés. Par exemple la femelle de la mouche de la cerise (Rhagoletis cerasi) peut pondre jusqu'à 80 œufs à raison d'un par fruit (INRA, web: hyppz).
– Le développement de la larve est endophyte. Sa destruction nécessite donc l'emploi de produits systémiques de synthèse.

Ces deux caractéristiques obligent l'utilisation de moyens de lutte extrêmement efficaces (organophosphorés) mais qui sont généralement préjudiciables pour l'environnement et non adaptés à des logiques d'agriculture raisonnée et biologique.

Une autre caractéristique du cycle de vie des Tephritidae pourrait bien être un atout pour la mise en place d'une lutte biologique. En effet, l'étape clef du cycle des mouches des fruits est la présence au sol d'un stade de conservation sous forme de pupe. Les larves ayant terminé leur développement s'enterrent dans les premiers centimètres du sol pour effectuer leur métamorphose. Ce stade de vie des mouches des fruits apparaît comme étant le plus vulnérable face aux arthropodes du sol, qui pourraient bien faire des pupes un de leurs mets favoris. Les Carabidae, sur lesquels sont principalement basées les expérimentations, constituent le groupe dominant d'arthropodes épiégés dans les agroécosystèmes de l'Europe tempérée et d'Amérique du Nord et leur abondance peut dépasser 10 000 individus à l'hectare (Dajoz, 2002). Sur le centre CTIFL de Balandran, le suivi des populations d'arthropodes épiégés en verger de cerisiers lors de l'année 2006 a montré que 40% des individus piégés appartenaient à cette famille. Non seulement cette famille de coléoptères est largement représentée par des espèces prédatrices pouvant être utiles dans la lutte contre les mouches des fruits, mais des études ont également démontré que leur présence dans le milieu était fortement liée aux techniques culturales, ce qui en fait de très bon indicateurs biologiques (Dajoz, 2002; Lee et al., 2001; Purtauf et al., 2005).

Une lutte biologique par conservation utilisant les arthropodes du sol pourrait être un moyen efficace de retrouver un équilibre des populations de ravageurs afin d'éviter les pullulations. L'équilibre retrouvé, il serait envisageable d'utiliser des méthodes de lutte plus "douces" que les insecticides organophosphorés.

Il s'agira donc d'identifier plus clairement le régime alimentaire des principales espèces d'arthropodes épiégés (Carabidae) essentiellement présentes en verger et dans un deuxième temps, de quantifier leur impact potentiel sur les populations de pupes au sol.

**Matériel et méthodes**

L'observation du régime alimentaire des arthropodes peut être réalisée de différentes manières : l'observation in situ, l'examen de l'appareil digestif, des tests au laboratoire, ou encore des méthodes sérologiques ou par PCR.

Lors de nos expérimentations 3 types de tests ont été effectués. Le premier est un test qualitatif au laboratoire qui a pour objectif de déterminer les préférences alimentaires des espèces étudiées. Le deuxième est un test quantitatif toujours en laboratoire qui consiste à comptabiliser le nombre potentiel de pupes consommées par un individu. Enfin le troisième est un test quantitatif in situ qui a pour objectif de déterminer quel est l'impact d'une population d'auxiliaires sur les populations de pupes au sol. Ce troisième essai est accompagné de tests par PCR afin de corroborer ou non la présence d'ADN de mouches dans l'appareil digestif des individus prélevés.

**Tests qualitatifs de préférence alimentaire en laboratoire**

Les tests sont réalisés en laboratoire à une température oscillant entre 23 et 26°C et avec une photopériode de 16h de jour et 8h de nuit. Leur objectif est d'observer sur 24 heures la
consommation d'un individu ayant jeûné 72 heures auparavant et à qui l'on présente un menu varié de proies. En l'occurrence, des larves et chrysalides de carpocapse des pommes (*Cydia pomonella*), des graines de composés et graminées, des pucerons et des pupes de mouche de la cerise (*Rhagoletis cerasi*) et mouche de l'olive (*Dacus oleae*). 5 proies de chaque type sont offertes par individu et 5 répétitions sont réalisées (1 individu = 1 répétition).

**Tests quantitatifs de consommation de pupes de mouches de l'olive**

Les tests sont réalisés en laboratoire dans les mêmes conditions que précédemment. Cette fois-ci, au lieu d'un menu varié, on présente aux individus testés seulement 15 pupes de mouche de l'olive.

**Test quantitatif de consommation de pupes de mouches de fruits in situ**

Le test est réalisé sur une zone enherbée sur le centre CTIFL de Balandran dans le Gard. La parcelle utilisée est située entre un verger de cerisier et une haie composée. Le procédé mis en place est un dispositif en blocs avec 3 modalités et 3 répétitions. Les 3 modalités sont :
- un témoin avec une libre circulation des arthropodes,
- une modalité positive qui ne permet que l'entrée des arthropodes dans la parcelle élémentaire et pas leur sortie,
- une modalité négative qui ne permet que la sortie des arthropodes et pas leur entrée.

Le dispositif mis en place autour des modalités positives et négatives est décrit dans la figure suivante : dispositif mis en place autour des modalités positives et négatives est représenté dans la figure 1.

![Figure 1. Dispositif de régulation de circulation des arthropodes épiçés](image)

Chaque parcelle élémentaire de 4m² est délimitée par une tranchée de 15cm de profondeur. Pour chacune d'entre elles, 2 pièges Barber sont disposés sur une diagonale du carré afin de suivre l'efficience du système mis en place sur les populations d'arthropodes (augmentation ou diminution des populations). De plus, sur l'autre diagonale du carré, on dispose des boîtes de Pétri emplies de terre dans lesquelles seront disposées les pupes. Les boîtes de Pétri sont recouvertes d'un abri permettant d'éviter les accidents dus à de fortes pluies et entourées de grillage afin d'éviter la prédation par les oiseaux ou des petits mammifères.
Résultats et discussion

*Test qualitatif de préférence alimentaire en laboratoire*

La figure 2 montre la cinétique de consommation pour une espèce donnée, en l'occurrence, *Harpalus affinis*.

Figure 2: Cinétique de consommation des différentes proies offertes à l'espèce *Harpalus affinis* (Coléoptères, Carabidae). Les valeurs suivies de lettres différentes sont significativement différentes au seuil \( \alpha = 0.05 \)

La consommation des différentes proies suit une exponentielle. Aucune différence de consommation n'a été notée entre les graines de composées, les pucerons et les pupes de mouches de l'olive. Seules les larves de carpocapse des pommes ont été moins consommées. L'espèce *Harpalus affinis* montre clairement son caractère omnivore et son efficacité potentielle en tant qu'auxiliaire dans la lutte contre les mouches des fruits.

Le bilan détaillé au bout de 24 heures pour les 5 espèces de *Carabidae* majoritaires des vergers de Balandran est présenté dans la figure 3. En ce qui concerne les autres espèces, celui-ci figure dans le tableau 1 et indique pour les espèces testées le nombre de pupes consommées lors des tests réalisés en 2005 et 2006.

Quatre des cinq espèces prédominantes en verger sont potentiellement intéressantes comme auxiliaires de lutte contre les mouches des fruits. Il est à noter que les cinq espèces ont aussi consommé des larves et chrysalides de carpocapse des pommes. Les *Carabidae* pourraient donc aussi jouer un rôle d'auxiliaire dans la lutte contre ce ravageur.

Dix des quatorze espèces testées ont consommé des pupes de mouches, dont cinq à des niveaux élevés. Ces dernières espèces (notamment les *Harpalus*) peuvent s'avérer intéressantes dans la lutte contre les mouches des fruits. Il est toutefois à noter que toutes ne se retrouvent pas régulièrement et dans les mêmes proportions dans les différents types de verger ce qui peut relativiser l'importance de certaines espèces.
Figure 3. Nombre de proies consommées en 24 heures par individu, pour les 5 espèces majoritaires en verger de Balandran – Test du 06/06/06. 6 proies différentes sont offertes à raison de 5 unités par proie et par individu. Le nombre de répétition est variable suivant les espèces : *A. aenea* (5), *C. fuscipes* (5), *H. affinis* (10), *H. distinguendus* (11), et *P. rufipes* (5).

Tableau 1: Consommation sur 24 h de pupes de mouche de l’olive en 2005 et de la cerise en 2006, en % de pupes offertes, selon les espèces de carabes et staphylin. 5 pupes offertes par individu ; 1 individu = 1 répétition. Les valeurs suivies de lettres différentes sont significativement différentes au seuil $\alpha = 0.05$

<table>
<thead>
<tr>
<th>Genus species</th>
<th>24/05/05</th>
<th>07/06/05</th>
<th>21/06/05</th>
<th>27/06/05</th>
<th>06/07/06</th>
<th>Total repetitions</th>
<th>% total consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Harpalus distinguendus</em></td>
<td>92% A</td>
<td>96% A</td>
<td>92% A</td>
<td>33% BC</td>
<td>26</td>
<td>93%</td>
<td></td>
</tr>
<tr>
<td><em>Ophonus rufipes</em></td>
<td>84% A</td>
<td></td>
<td></td>
<td></td>
<td>10</td>
<td>84%</td>
<td></td>
</tr>
<tr>
<td><em>Harpalus affinis</em></td>
<td>84% A</td>
<td>60% AB</td>
<td>60% A</td>
<td>56% B</td>
<td>25</td>
<td>68%</td>
<td></td>
</tr>
<tr>
<td><em>Harpalus pygmaeus</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>48%</td>
<td></td>
</tr>
<tr>
<td><em>Calathus fuscipes</em></td>
<td>48% B</td>
<td>0% B</td>
<td>40% A</td>
<td>40% B</td>
<td>20</td>
<td>29%</td>
<td></td>
</tr>
<tr>
<td><em>Cylindera germanica</em></td>
<td>16% B</td>
<td></td>
<td>10% B</td>
<td></td>
<td>9</td>
<td>13%</td>
<td></td>
</tr>
<tr>
<td><em>Ditomus capito</em></td>
<td></td>
<td></td>
<td></td>
<td>8% CD</td>
<td>5</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td><em>Zabrus tenebiroides</em></td>
<td></td>
<td></td>
<td></td>
<td>8% CD</td>
<td>5</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td><em>Ophonus cribicollis</em></td>
<td>12% B</td>
<td>0% C</td>
<td></td>
<td></td>
<td>10</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td><em>Amara aenea</em></td>
<td>4% B</td>
<td>0% C</td>
<td></td>
<td>0% D</td>
<td>15</td>
<td>2%</td>
<td></td>
</tr>
<tr>
<td><em>Brachinus sclopeta</em></td>
<td>0% B</td>
<td>0% C</td>
<td></td>
<td></td>
<td>10</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td><em>Microlestes sp.</em></td>
<td>0% B</td>
<td></td>
<td></td>
<td>0% NS</td>
<td>6</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td><em>Nebria brevicollis</em></td>
<td></td>
<td></td>
<td></td>
<td>0% D</td>
<td>5</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td><em>Ocypus olens</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>0%</td>
<td></td>
</tr>
</tbody>
</table>

Tests quantitatif de consommation de pupes de mouches de l’olive

3 espèces ont été testées : *Pseudophonus rufipes* (Carabidae), *Calathus fuscipes* (Carabidae) et *Ocypus olens* (Staphylinidae). Le graphique ci-dessous indique la consommation en pupes des trois espèces en fonction du temps.
Figure 4. Nombre de pupes de mouche de l'olive consommées sur 24h par 3 espèces d'arthropodes présentes en verger de Balandran : *Pseudophonus rufipes* (Carabidae), *Calathus fuscipes* (Carabidae) et *Ocypus olens* (Staphylinidae).

*P. rufipes* est l'espèce la plus consommatrice de pupes avec une consommation potentielle *in situ* de 12.6 pupes/jour (+/- 2.1). Les deux autres espèces *C. fuscipes* et *O. olens* montrent des consommations plus faibles proches de 50%, soit respectivement 7.8 (+/- 2.1) et 6.3 (+/- 2.1) pupes/jour.

**Test quantitatif de consommation de pupes de mouches de fruits *in situ***

L'objectif de l'essai était de quantifier l'impact des populations d'arthropodes sur les populations de pupes de mouches au sol. Pour cela trois modalités ont été mises en place, chacune avec des apports artificiels de pupes de mouches de l'olive au sol : une modalité enrichie en arthropodes, une modalité appauvrie et une modalité témoin avec libre-circulation des individus. Le tableau 2 indique les résultats concernant l'efficacité du système de modulation des populations et ce pour la population totale et pour les principaux groupes d'arthropodes prédateurs.

Le système de modulation des populations a en partie fonctionné. En effet, bien que la modalité enrichie ne comporte pas de différences avec le témoin, la modalité appauvrie est quant à elle significativement différente des 2 autres, pour la majorité des groupes d'arthropodes susceptibles d'être prédateurs de pupes de mouches. En effet, pour l'ensemble de la population, on trouve 74% d'individus en moins dans la parcelle appauvrie par rapport à la parcelle témoin et par exemple, pour les *Carabidae*, 85%. En ce qui concerne le groupe des *Staphylinidae*, aucune différence n'a été observée entre les modalités. Ce phénomène s'explique probablement par le faible nombre d'individus récoltés, de plus la majorité des staphylins, en particulier les espèces de petite taille volent et ne sont, par conséquent, pas affectés par les barrières au sol.

En parallèle des relevés de populations, 6 apports de pupes ont été réalisé du 05/05/06 au 04/12/06. Aucun des apports en montre de résultats significativement différents entre les modalités. Il en va de même pour la moyenne des consommations (Fig. 4). La consommation maximale de pupes pour une parcelle élémentaire est de 30 par jour, soit près de 37 000 pupes potentiellement consommées à l'hectare.

En complément des relevés de populations d'arthropodes, 50 individus ont été prélevés au hasard lors de l'expérimentation afin de détecter ou non la présence dans leur système digestif d'ADN de mouche de l'olive. Sur les 50 individus testés, 10 répondent positivement
au signal de la mouche de l'olive. Parmi eux, on compte 2 Aranéides (famille des Gnaphosidae), 5 carabes (A. aenea, D. capito, O. sabulicola, O. subquadra
tus), 2 Formicidae, et 1 Staphylinidae).

Tableau 2: Mesures de l'efficacité du système de régulation des populations d'arthropodes épigés. Les valeurs suivies de lettres différentes sont significativement différentes au seuil $\alpha = 0.05$

<table>
<thead>
<tr>
<th>Concerned arthropods</th>
<th>Methods</th>
<th>Number of arthropods/method</th>
<th>Statistic group (5%)</th>
<th>Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>-</td>
<td>32</td>
<td>B</td>
<td>Newman-Keuls</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>92</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>122.7</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td><strong>Araneids</strong></td>
<td>-</td>
<td>6</td>
<td>B</td>
<td>Mann-Whitney</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>22.7</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>31</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td><strong>Coleopters</strong></td>
<td>-</td>
<td>5</td>
<td>B</td>
<td>idem</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>23</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>21.7</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td><strong>Carabidae</strong></td>
<td>-</td>
<td>2.6</td>
<td>B</td>
<td>idem</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>18</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>17</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td><strong>Staphylinidae</strong></td>
<td>-</td>
<td>0.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>1.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lycosidae</strong></td>
<td>-</td>
<td>2.67</td>
<td>B</td>
<td>Mann-Whitney</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>17</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>18</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td><strong>Formicidae</strong></td>
<td>-</td>
<td>8</td>
<td>B</td>
<td>Mann-Whitney</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>21</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>46</td>
<td>A</td>
<td></td>
</tr>
</tbody>
</table>

Une réserve est toutefois nécessaire à l'analyse des résultats. En effet, lors d'une grande partie des relevés des lits de pupes, ceux-ci étaient consommés en intégralité (40% des relevés). Par conséquent, aucune différence de consommation entre les modalités ne pouvait ressortir. Ce phénomène est sans doute responsable du nivellement des résultats entre les 3 modalités. Il aurait donc été nécessaire de placer plus de pupes à chaque apport, de plus l'absence de différences entre les 3 modalités du dispositif met en exergue les limites de celui-ci. En effet, il n'y pas de contrôle des insectes volants et des insectes de petite taille qui sont semble t'il capables de grimper sur la paroi en PVC ; tel est le cas pour les petites espèces de fourmis par exemple. Ces dernières ont certainement joué un rôle important dans la consommation des pupes, d'une part parce qu'elles répondent positivement au signal PCR et d'autre part, il a été remarqué par observation, lors de la chute des larves au sol en verger de cerisiers, une prédation importante par les fourmis, qui capturent les asticots et les emmènent à la fourmilière.
Figure 4. Relevés des consommations de pupes de mouches de l’olive dans les 3 modalités étudiées. Les valeurs suivies de lettres différentes sont significativement différentes au seuil $\alpha = 0.05$.

Bilan des résultats

1. 10 des 14 espèces rencontrées en verger de Balandran et testées en laboratoire ont consommé des pupes de mouches.
2. Un individu peut consommer en laboratoire, jusqu’à 12 pupes par jour
3. La diminution des populations d’arthropodes par la mise en place du dispositif expérimental n’influence pas la quantité de pupes consommées au sol.
4. La consommation en pupes par les arthropodes du sol peut atteindre jusqu’à 37000 unités/ha
5. La diversité des auxiliaires pouvant être utiles dans la lutte contre les mouches des fruits est importante (Aranéides, Carabidae, Staphylinidae, Formicidae).

Références bibliographiques

Orchard susceptibility of stone-fruit cultivars to Xanthomonas arboricola pv. pruni

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Abstract: Bacterial spot of stone fruit is caused by a pathogen detected in France in 1995: Xanthomonas arboricola pv. pruni (Xap) causes severe losses at harvest for growers in the south of France. Faced with the impossibility of controlling this pathogen with pesticides when climatic conditions are favorable for its development, it is necessary to turn to varietal susceptibility as a solution. Thus Ctifl has undertaken a study in a contaminated area to determine the level of susceptibility to this disease of a hundred peach, apricot and plum varieties planted in 2002, 2004 and 2006. For the 50 varieties planted in 2002, five years observations on incidence and severity of the attacks on leaves and fruits have resulted in the level of the damage caused by Xap according to the cultivar to be determined. The data for the varieties planted more recently are still insufficient, the levels of damage observed in 2005 and 2006 were low, due to unfavorable climatic conditions for disease development.

Key words: Xanthomonas arboricola pv. pruni, varieties susceptibility, peach, apricot, plum.

Introduction

Xanthomonas arboricola pv. pruni (Vauterin et al.,1995; syn. X. campestris pv. pruni ((Smith) Dye, hereafter cited as Xap) is an important pathogen of stone fruit trees. It was first described in North America in 1903 by Smith. In Europe, it was first recorded in Italy in 1920. In France, Xap was reported for the first time in 1995 in the Costières du Gard region (in the south of France). This bacterium is responsible for important losses at harvest. This disease was severe in 2000 in the Gard region, and has continued to expand in stone fruit orchards. For the moment, no pesticide is available against this pathogen, because none are efficient on Xap. It is thus necessary to find solutions by the means of varietal choice. The Ctifl is carrying out varietal sensitivity tests in contaminated zones. Different stone fruit varieties were planted in 2002, 2004 and 2006. This experimental study on varietal susceptibility will allow farmers, nursery gardeners and obtainers to quickly find out the susceptibility of varieties before planting. The Xap contamination is dependant on the climate. Previous studies show that infestation is favoured by: rain, temperatures around 20°C, and a moistening period for at least 8h (Battiliani et al., 1999, Garcin et al., 2005). Rain and moistening are influencing factors for the disease because they can create hydrous congestion on leaves and allow the bacterium to enter the plant. So, the climate is one of the factors responsible for variations in the behaviour of varieties towards Xap. In this respect, it seemed interesting to study Xap infection according to climate.
Materials and methods

Varieties
A first series of 50 varieties was planted in 2002 (Garcin et al., 2007). In 2004, another series of 36 varieties was chosen to complete data on varietal susceptibility: 2 apricot varieties, 3 plum varieties and 32 peach varieties. And, finally, 19 varieties (3 apricot and 16 peach) were planted in 2006. Here we only present the results obtained for 2002 plantation. These varieties were chosen amongst those already on the market.

Orchard
It is located in Vestric et Candiac, in the Gard region. The chosen plots are in a Xap contaminated environment surrounded by peach trees that had shown symptoms of the disease for several years. This was to ensure that there was sufficient inoculum present so that the young trees would be rapidly contaminated. There are 9 trees for one variety, which means 3 repetitions of 3 trees. A block device is used. A susceptible control variety was used for each species: 1 control variety every 6 trees. The control variety is Big Sun® Maillerbig for peach, Goldbar® Toyiba for apricot and Fortune for plum. Plantation distances: 5m x 1,7m. Irrigation by aspersion under foliage was used.

Observations
a) Disease severity ratings on leaves in the orchard.
b) Disease severity ratings on fruit harvest (incidence and severity for 100 fruits for each plot)

Results
The experimental orchard was planted in 2002 but observations on fruits began in 2003. Disease assessment on fruit is more important for growers than on leaves. Since 2003, damage has been rated each year. The relation between fruit losses and moistening of the foliage in April is reported on Figure 1.

Figure 1. Comparison of the damage observed on peach fruit and the moistening of the foliage in April, for the 2003-2006 period.
This figure shows that the moistening in April is close to the real damage observed. According to David Ritchie, frequent periods of rainfall and/or foliage moistening from late petal fall until approximately 4 weeks later are associated with severe bacterial spot on fruit. Consequently, the results may be modulated according to the year. So, we worked on the results converted into non-parametric data. We present only results on 2002 planting cultivars.

Differences can be observed according to the rank transformation (Fig. 2, 3 and 4). It influences the varieties classification. For example, O’Henry® is regularly infested on fruits, even unfavourable years, but at a low level. On the other hand, Big Top® is infested at a high level but not every year. These results don’t correspond to the existing classification of varietal susceptibility. For apricots and plums, relation between incidence and rank transformation is better.

**Discussion**

The first observations on the 2002 series allow Xap sensitivity to be evaluated using three categories (Table 2): Highly susceptible (meaning more than 10% incidence since 2004), susceptible (meaning more than 0% incidence to 10%), and slightly susceptible (0% incidence). Still, this classification is arbitrary and it can evolve in the future.

![Figure 2. Incidence on fruits for the 2002 peach plantation with or without rank transformation.](image-url)
Figure 3. Incidence on fruits for the 2002 apricot plantation with or without rank transformation.

Figure 4. Incidence on fruits for the 2002 plum plantation with or without rank transformation.
Table 2. *Xanthomonas* behaviour on peaches taking a climatic coefficient into account, after 3 years of observations

<table>
<thead>
<tr>
<th>Variety</th>
<th>Highly susceptible</th>
<th>Susceptible</th>
<th>Lowly susceptible</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Apricot</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goldbar®</td>
<td>Bergeron</td>
<td>Bergarouge®</td>
<td></td>
</tr>
<tr>
<td>Goldrich</td>
<td>Kioto Cov</td>
<td>Early Blush®</td>
<td></td>
</tr>
<tr>
<td>Hargrand</td>
<td>Orangered®</td>
<td>Sylred (1)</td>
<td></td>
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<tr>
<td></td>
<td>Pinkcot®</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Polonais</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Peach</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Big Sun®</td>
<td>Ambre®</td>
<td>Belbinette®</td>
<td></td>
</tr>
<tr>
<td>Big Top®</td>
<td>Coralie cov</td>
<td>Benedicte®</td>
<td></td>
</tr>
<tr>
<td>Diamond Princess cov</td>
<td>Coraline®</td>
<td>Diamond Bright cov</td>
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<tr>
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<td>Flameglo®</td>
<td>Emeraude®</td>
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<td>Jade®</td>
<td>Gladys®</td>
<td>Plusplus®</td>
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<tr>
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<td>Red Fair®</td>
<td>Spring White® (1)</td>
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<td>Rich Lady cov</td>
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<td>Snow Ball cov</td>
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<tr>
<td></td>
<td>Zeeglo cov</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Plum</strong></td>
<td></td>
<td>Golden Japan</td>
<td></td>
</tr>
<tr>
<td>Tc Sun</td>
<td></td>
<td>Black Amber</td>
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<tr>
<td></td>
<td></td>
<td>Fortune</td>
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<td></td>
<td></td>
<td>Mirabelle De Nancy</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td>Prune D’ente</td>
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<td></td>
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<td>Reine-Claude Doree (1)</td>
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</tbody>
</table>

**Conclusion**

Now, growers dispose of this susceptibility varietal list which can aid them to make a choice for their orchard varieties. A new orchard was planted in 2006 in order to continue this varietal sensitivity study. Knowing the varietal Xap susceptibility of a given variety represents the only way of limiting bacterial spot disease, associated with prophylactic measures. No resistant varieties exist today but research continues.

**References**


Smith, E.F. 1903: Observations on a hitherto unreported bacterial disease, the cause of wich enters the plant through ordinary stomata. – Science 17: 456-457.

Damages by *Capnodis tenebrionis* in Stone-Fruit orchards in Northern Italy

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**Abstract:** Apricot cultivation is very important for some Italian Regions, particularly for the hilly countries of Romagna (in Northern Italy). In that area, orchards have been set up on clayey soil, often without possibility of irrigation.

Among apricot pests, *Anarsia lineatella* has always been considered as a key species. In the last few years heavy attacks of Flatheaded Woodborer *Capnodis tenebrionis* (Coleoptera: Buprestidae) have been observed in plots without irrigation. Infestations were particularly heavy in young orchards. *C. tenebrionis* is a tipical pest of Southern Italy and it never caused great damage in norther regions. Studies concerning adult’s behaviour, oviposition and larval behaviour started in 2003 in an Appennine area of Bologna province. Some comments on the damage levels and on possible pest control activities are reported.

**Key words:** Apricot, irrigation, *Capnodis tenebrionis*, control

**Introduction**

Italy vies with Spain for the title of Europe’s biggest producer of apricots and the Emilia-Romagna region produces just under 30% of the national total, cultivated on about 4,860 hectares. Romagna, in particular the area of the foothills which run through the provinces of Bologna, Ravenna and Forlì, is one of this fruit plant’s most important growing areas. Apricots have long been cultivated here and the old local varieties have been replaced, either completely or almost, by new cultivars.

Apricot orchards are often set on clayey soil on hillsides, sometimes without irrigation systems, as apricots can thrive on soils which contain little water during the summer months.

There are at least fifteen phytosanitary problems which affect the apricot, but there are few present at such levels as to require control measures, such as the insects *Contarinia pruniflorum, Anarsia lineatella* and the phytopathogens, *Monilia laxa, Coryneum beijerinkii, Pseudomonas syringae* pv. *syringae* and, finally, *Apiognomonia erytrostoma*.

In recent years apricot farms on clayey soils, lacking irrigation systems, have been particulary prone to attacks by *Capnodis tenebrionis* (Linné, 1761) (Coleoptera Buprestidae) which have caused irreparable damage and destroyed entire young orchards, in the same way as it happens in the Southern cultivation areas of the Mediterranean basin in stone fruit orchards (Liotta & Maniglia 1994, Russo et al., 1994, Ben-Yehuda et al., 2001, Ciglar et al., 2004).

The jewel beetle is very common, particularly in southern Italy and the islands, while in the apricot growing areas of Emilia-Romagna, although it has been sporadically present in the past, has never created problems as it has only been found on very old plants, causing negligible damage.

During particularly dry summers conditions are favourable for *C. tenebrionis* and its populations have continuously increased up to levels that cause considerable damage.
In the light of the appearance of these serious infestations it has been decide opportune to carry out research in Romagna in order to identify possible remedies to limit damage.

Research has been ongoing since 2003 in cultivations with serious infestations of the pest in the Imola (BO) area, in the town of Borgo Tossignano (BO), where apricots have long been cultivated and where the highest concentration of drupacea is found.

**Observations on the behaviour of adults**

Adults are present in the field for a large part of the vegetative period of the plants, from late April – early May, throughout September. At the beginning of the season the populations which have survived the winter underground predominate, and later new adults appear.

At the beginning of spring in late April-early May they begin to be active, even if in rather limited way, but activity intensifies from mid May when temperatures rise above 24-25°C. During the warmest part of the day they are to be found on branches with less vegetation which are most exposed to the sun.

Their trophic activity is not particularly intense, as our observations indicated that sexual maturity is reached in the previous autumn, when coupling occurs. In fact, dissection of the bodies of several tens of females collected in field in mid September revealed eggs at different developmental stages inside the oviducts and in only a few cases were the oviducts empty. Adults captured in mid September were mostly females and this would seem to be further evidence that coupling had already occurred, considering that after carrying out their reproductive role males die quite quickly.

New adults appear from the month of June, with maximum presences in August and September (De Lillo, 1998). The trophic activity of the new adults is particularly intense, favoured by high summer temperatures and this continues, though progressively less intensely, until the end of the autumn.

**Observations on ovipositions**

Ovipositions start in the month of June, attaining maximum intensity in midsummer, the hottest period, and continue until September. Eggs are mainly deposited at the neck or not more than 10 centimetres from the trunk. They are deposited on the cortex of the neck and the emerging roots, but the females oviposit mainly on ground surfaces and a few centimetres underground, after thrusting their abdomens into the ground and rapidly evert ing the ovipositor. As noted in the literature the eggs are particularly sensitive to excesses of humidity in the soil, and considering that this is the most common oviposition site it follows that the state of summer aridity of clayey non-irrigated soils leads to a high percentage of closure of eggs with a subsequent development of considerable larval populations and a continuous increase in the size of capnodis populations.

**Larval behaviour**

Newborn larva manage to make contact under the soil with the trunk and roots, moving thanks to tufts of long locomotory hairs on the sides and caudal extremity, managing to cover, it would seem, vertical or horizontal distances of up to 15 cm. Once they have penetrated the cortical tissues they no longer protrude, completing their development in 1-2 years inside their tunnels, at the end of which, once maturity is reached, an oval pupation cell is formed to give to the new adults after a prenymphal period of about two weeks and a nymphal period
which lasts around another three weeks. It has been observed that when the plant dies and the roots dry up the immature larva are unable to complete their development and die being unable to attack the root systems of nearby plants.

**Damage caused**

The adults break off the leaf-stalks causing severe defoliation, as is clear from the quantities which build up on the ground beneath the crown of plants attacked. As well as defoliating plants the adults damage the smallest twigs, leaving the larger ones, decortication causing emissions of rubber from the affected areas.

Damage caused by adults is particularly severe on young plants, but on adult plants too this is aggravated by that produced by larva and accelerates decline. Larval attacks cause great damage and young plants are irreparably damaged and die in one or two years, while adult plants are weakened and though they may struggle on for a while, eventually succumb.

Damage by *C. tenebrionis* involves plants in clayey soils and cultivations which, with no irrigation systems, are more exposed to the stresses caused by summer drought. In 2003 *C. tenebrionis* attacks were particularly destructive, when the summer was very dry and hot.

Few, or even non-existent, are, on the other hand, attacks on cultivations on less clayey soils with irrigation systems.

**Control**

For protection against attacks by the pest in areas in which the insect is present in large abundant populations it is very important to provide apricot cultivations with irrigation systems as we know that soil humidity is the cause of very high mortality rates for eggs.

Insecticidal control is difficult because of the lack of availability of insecticide formulation which, even if they have been registered for the apricot, have not been approved for the beetle. Only for the late ripening cultivars can insecticide be used against *C. tenebrionis* adults with the organophosphate azinphos-methyl for larvicidal application during the first ten days of June against the peach twig borer. It is vitally important that the treatment takes place in the early morning so that the insecticide sprayed dries slowly and has as long a time as possible to kill the adults, which, still numb from the night cold, are not very mobile.

**References**


Un ravageur émergent, *Cossus cossus*

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**Abstract:** Le retrait des oléoparathions a laissé un vide dans la protection contre ce ravageur sur cerisier. Les traitements à la lance en post récolte étaient une technique détestée des producteurs, la seule homologuée, d’ailleurs. Réalisée sur les pontes fraîches et les toutes jeunes larves n’ayant pas eu le temps de s’insérer trop profondément sous l’écorce, la méthode avait une bonne efficacité sur les parcelles modérément atteintes. Même si le cerisier est l’espèce la plus communément attaqué, le cossus très polyphage, a profité de cette situation pour élargir son champ d’action. En effet les partenaires du réseau PFI (la Pugère) nous ont signalé cette année plus de dégâts que de coutume sur pommier. Cela est peut être déjà un effet secondaire lié à l’allègement des traitements insecticides suite à la forte implantation de la confusion sexuelle dans la région. Par ailleurs le SRPV Midi-Pyrénées nous a signalé des attaques sévères sur prunier. Dès l’an 1999, un réseau de pièges coordonné par la Tapy a été mis en place afin d’apporter quelques éléments sur la biologie de ce lépidoptère, qui est par ailleurs relativement mal connu. Les informations les plus consistantes ont été compilées par Balachowsky et Audemard qu’ils s’agissent de données bibliographiques ou des observations en élevages. Ces travaux ont orientés les observations biologiques que nous avons réalisées et suite au retrait annoncé des oléoparathions nous avons immédiatement mis en place en partenariat des études visant un point faible du cycle du cossus. Il s’agit de badigeon, qui constitue une barrière mécanique (ou mécanique et insecticide). La technique peut potentiellement gêner les adultes qui cherchent un lieu de ponte mais surtout les larves néonates qui sont réputées très fragiles (H. Audemard, 1974). Les essais par nature pluriannuel arrivent maintenant presque à leur terme, les résultats encourageant ont déjà abouties à l’homologation de l’ARBOPAST en traitement généraux zeuzère et cossus.

**Mots clefs:** *Cossus cossus*, badigeon, insecticide, arboriculture

**Préambule**

Le cossus peut être assimilé aux maladies orphelines en médecine: il concerne un nombre limité d’arboriculteurs, mais il est cependant très dommageable pour ceux là! La chenille de ce grand lépidoptère aux mœurs essentiellement nocturnes réalise des galeries de très grosse taille dans les troncs d’arbre ce qui aboutit année après année à la mort de l’arbre. Il est actuellement en recrudescence, et pas seulement sur cerisier. Sans doute l’aggravation des dégâts liés au Cossus fait suite au retrait d’un certain nombre de matières actives et à l’évolution des pratiques culturales.

Sans une collaboration étroite entre la COPEBI, le Domaine Expérimental La Tapy, et le SRPV PACA, il n’aurait pas été possible de réaliser une étude sur le cossus dans le calendrier des autres activités prioritaires. Aussi, nous sommes heureux de pouvoir vous présenter ici quelques résultats et de pouvoir proposer un début de solution dans la lutte contre cet insecte.
Il ne s’agit que d’un état des lieux sur l’avancement de nos observations, et nous n’avons pas la prétention non plus de réaliser ici une monographie complète sur ce ravageur.

**Situation sur le terrain et état des connaissances:**
Le cerisier est l’espèce cultivée la plus communément attaquée. Le cerisier d’industrie est particulièrement exposé: les blessures liées au secouage des arbres pour la récolte constituent autant de sites d’attaque privilégiés pour le cossus. Par ailleurs, il faut signaler actuellement une recrudescence du cossus sur pommier, sans doute liée à l’allègement de la lutte insecticide contre le carpocapse des pommes grâce à la confusion sexuelle. A remarquer, enfin, l’émergence du problème dans le Sud-Ouest sur prunier.

La bibliographie concernant le cossus est assez réduite, les informations compilées par Balachowsky (1966) et des suivis réalisés par Audemard (1974) nous ont cependant donné les bases de biologie pour travailler sur cet insecte. Signalons que l’INRA a réalisé un rapport conséquent en 1991 sur différents ravageurs du bois (Audemard et Causse, 1991). Nous avons aussi apprécié une documentation sans équivalent réalisée par André Lequet (retraité de l’Université de Nantes), qui n’a pas fait l’objet d’une publication à notre connaissance, mais qui est disponible sur son site Internet «les pages entomologiques d’André Lequet». Monsieur Lequet a réalisé des observations en élevant, de la ponte à la diapause. D’une manière générale, l’insecte a un cycle qui dure 2 à 3 ans sous climat français, parfois plus dans les régions les plus froides. Des auteurs cités par Balachowsky mentionnent sa présence sur artichauts, et autres espèces maraîchères, et précisent aussi qu’il peut réaliser des loges de sciure, de sécrétions, soit sous un débris végétal, soit dans le sol. Sur cerisier nous observons cela autour du collet le plus souvent. D’après Balachowsky, les pontes se réalisent «à hauteur d’homme» dans la fourche des arbres, mais nous supposons que d’une manière générale, les zones blessées ou présentant des écorces craquelées sont privilégiées. Le nombre d’œufs est très important (pouvant atteindre 1300 d’après les observations d’André Lequet). Dans la pratique, sur un arbre, nous n’observons que très rarement plus de 50 larves de grande taille sur un tronc de cerisier. Cela confirme un point important mentionné par Balachowsky: la vulnérabilité des jeunes larves.

Enfin, sans doute grâce à des signaux chimiques, une attaque de cossus sur le tronc attire souvent ses congénères, qui, au bénéfice des trous d’émergences ou de galeries temporaires pondent et s’acharment jusqu’au dépérissement complet de l’arbre.

**Les suivis biologiques**
La lutte contre un ravageur passe par la connaissance de son cycle: l’insuffisance notoire des données bibliographiques a amené les partenaires de cette étude à organiser une collecte d’informations sur ce ravageur : qu’il s’agisse de l’établissement d’une courbe de vol, capitale pour positionner d’éventuelles applications insecticides, ou d’observations des larves sur les troncs d’arbres.

**Courbes de vol**
Le Domaine Expérimental La Tapy a animé de 1999 à 2003 un réseau de piégeage établissant ainsi une courbe de vol moyenne pour les zones de production de Provence. On constate que l’essentiel du vol a lieu entre mi-mai et fin juillet. Ces données pourraient faire l’objet d’une modélisation sommaire si le besoin s’en faisait sentir pour positionner d’éventuels insecticides.

**Piégeages et observations**
Par analogie avec ce qui se passe avec des insectes lignivores ou réalisant des mines sur pousse (comme la zeuzère ou la tordeuse orientale du pêcher) nous avons pensé qu’il y avait une phase migratoire à une période de l’année. Il y a un autre indice: beaucoup d’arbres présentent des sorties de sciure sous la fourche, alors que nous n’observons pas de galeries sur
le tronc et qu’au collet il y a de nouveau une forte présence, avec souvent des grosses larves. L’ensemble des partenaires a réalisé un grand nombre de curetages à la gouge sur des essais ou lors de diagnostics. Nous pouvons affirmer qu’autour du collet il n’y a pas seulement de grosses larves, mais aussi des larves de l’année. Il nous paraît très probable qu’à l’automne, les larves préfèrent se situer près du niveau du sol, voire sous le niveau du sol pour hiverner. Cela est aussi cohérent avec les observations de diapauses réalisées sur pivot de betterave et tiges d’artichaut signalées dans la bibliographie (Ugolini et Genduso, in Balachowsky, 1966).

Le SRPV menant régulièrement des campagnes de dénombrement du carpocapse des pommes à l’aide de bandes pièges en carton ondulé serrées sur le tronc, nous avons tenté d’étendre au Cossus ce mode de piégeage. Un foyer de Cossus à proximité du Domaine Expérimental La Tapy a permis de relever régulièrement ces pièges. D’un point de vue quantitatif, ce dispositif s’est révélé manifestement insuffisant, aussi nous avons abandonné provisoirement cette piste comme méthode de lutte. Nous avons néanmoins constaté la présence de cossus de tailles et donc de stades et d’âges différents dans les bandes, parfois avec réalisation de cocons de sécrétion, de carton mâché, de sciure et d’excréments. Nous avons observé quelques fois une galerie qui débouchait sous le cocoon, mais souvent l’écorce était saine sous le piège. Nous avons donc confirmation que la chenille se déplace parfois à la surface du tronc. A différents stades de son développement, le cossus est donc exposé au contact avec l’écorce : lors de la ponte, à l’éclosion, et lors de ses phases migratoires. Nous avons tenté de mettre à profit cette caractéristique en appliquant une protection mécanique ou mécanique et insecticide par un badigeonnage du tronc à la lance, soit avec un badigeon seul, soit avec un badigeon additionné d’insecticide.

Les badigeons, des pistes intéressantes dans la lutte contre le cossus.

Le Domaine Expérimental La Tapy avait réalisé un essai pluriannuel de lutte par piégeage massif contre le cossus sur une parcelle de cerises d’industrie (variété Raynier) située près de Bollène. L’expérimentation avait conclu à l’insuffisance de la méthode de lutte étudiée pour la zone de production considérée (Berud et Marty, 2004), par contre elle laissait derrière elle une parcelle avec un historique rigoureusement enregistré et cartographié des dégâts de cossus : elle constituait donc un support idéal pour mettre en place une nouvelle étude. C’est cette parcelle sur laquelle les 3 partenaires ont mis en place un essai visant à mesurer l’efficacité d’une protection soit par badigeonnage (avec la spécialité Arbopast) soit avec un badigeon additionné d’un insecticide (avec les spécialités Arbopast + Decis). Le choix du Decis comme insecticide s’est basé sur les connaissances que nous avions tant sur ses vertus répulsives (comme de nombreuses pyréthrinoïdes) que sur sa persistance dans des badigeons. Une communication orale avec nos homologues au Magreb nous a conforté dans ce choix, l’Afrique du Nord étant très sensible aux attaques de ce type de ravageur, des tentatives y ont déjà été menées.

Méthodologie

Protocole

Vu la répartition très irrégulière des attaques sur une parcelle, avec tout de même des effets de foyer, et vu l’encombrement au sol d’un cerisier (64 m² sur cette parcelle) nous avons d’emblée rejeté les plans d’essai comportant des parcelles élémentaires de plusieurs arbres. Il serait en effet illusoire d’atteindre une puissance statistique suffisante sur un dispositif à taille « humaine », et de toute façon on aurait ensuite une hétérogénéité physique entre les parcelles. Nous avons donc choisi de réaliser des analyses non paramétriques, le bloc élémentaire étant un triplet d’arbres réunissant les trois traitements (dont le témoin non traité).
La lourdeur de mise en place de l’essai et la nécessité pratique de réaliser les traitements dans la journée pour une équipe de 4 à 6 personnes font que nous n’avons pas pu réaliser des triplicats appareillés d’arbres ayant le même historique, cela aurait par ailleurs été difficile et aurait accru considérablement la surface de l’essai, les erreurs potentielles lors des traitements, l’hétérogénéité du verger étudié. Dans le traitement statistique, cette donnée a été prise en compte. Au début de l’essai, nous avions 33 arbres pour chacune des 3 modalités. La figure n. 1 schématisse la répartition des modalités sur l’essai.

**Application**

Les traitements insecticides ont été appliqués sur le tronc jusqu’à la fourche et au collet de l’arbre, où des racines apparentes peuvent constituer d’éventuelles portes d’entrée pour des larves en déplacement (les pontes ne nous ont encore jamais été signalées au collet). Concernant l’efficacité dans le temps d’un badigeon insecticide, la société Protecta, qui met Arbopast sur le marché, nous a fourni un essai montrant qu’un badigeon (Arbopast + Decis Protech) sur tronc de cerisier de 3/10 de millimètre conservait au bout de 4 mois une efficacité insecticide de 100% sur mouche domestique. Le produit, dilué conformément à l’étiquette, ne pose pas de problème de bouchage des buses s’il est agité régulièrement, et si le matériel est rincé abondamment après usage, avant séchage, avec une spécialité adaptée au nettoyage des pulvérisateurs. Arbopast est employé à la dose de 1 litre pour trois litres d’eau. Les doses de Decis ont été calculées pour atteindre sans dépasser à l’hectare la dose autorisée sur l’usage Puceron noir/Cerisier. S’agissant de vieux cerisiers de gros diamètre, il a fallu apporter 750 millilitres de bouillie par arbre, ce volume mérite rarement d’être dépassé. Sur de jeunes plantations, le volume de bouillie pourrait être réduit très significativement (et donc aussi la dose hectare de Decis).

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**Figure 1. Arbopast: cumul du nombre d’arbres attaqués.**

**Notation**

Les notations sont réalisées tous les ans à l’automne depuis l’année 2001, en notant les dégâts récents attribuables à des larves vivantes au cours de la campagne, ainsi que, la première année de mesure, les dégâts anciens. Pour les analyses statistiques, nous avons choisi de ne pas utiliser les données quantitatives : elles constituent un estimateur peu performant. En effet seule une destruction de l’arbre peut donner une idée des populations de larves réellement présente dans le tronc et autour du collet. Le dénombrenement visuel des trous avec sciure fraîche et des amas de sciure ne s’avère pas fiable du tout : sur des arbres ne présentant que 2 ou trois symptômes apparents, nous avons parfois trouvé plusieurs dizaines d’individus après un curetage minutieux, de plus cette opération mécanique met l’arbre en péril de façon plus rapide que le cossus. Nous avons donc toujours utilisé comme donnée de base la valeur binaire [attaque l’année N/pas d’attaque l’année N].

**Durée d’étude**

Par nécessité, vu le cycle de l’insecte, l’étude est pluriannuelle. En effet, les notations réalisées les deux premières années révèlent des dégâts issus de chenilles qui ont éclos avant que la protection n’ait été mise en place, il convient donc d’analyser les résultats sur une durée supérieure ou égale à 3 ans. La lenteur de mise en place d’un tel essai et la difficulté de le multiplier fait que nous poursuivons l’étude encore aujourd’hui, afin de valoriser le dispositif existant. Il est évident qu’il conviendra aussi de mettre en place des essais plus nombreux, sur des parcelles coupées en trois modalités, pour vérifier la viabilité de la lutte à l’échelle de la parcelle.

**Résultats et discussion**

Les résultats (figure n. 1-2) montrent que l’Arbopast seul a une efficacité non négligeable dans la réduction des dégâts liés au Cossus, qui peut s’avérer essentielle pour la survie d’un verger sur le long terme. Cette différence est significative, qu’on réalise un test de proportion ou un test non paramétrique. Il faut avoir en tête que l’intensité de l’attaque n’est pas évaluée, et que nous pouvons ainsi surévaluer ou plus probablement sous évaluer l’efficacité des modalités étudiées.

La figure n°4 révèle que l’apport lié à l’insecticide pourrait accroître de façon intéressante l’efficacité du badigeon (si on exclut l’évolution des attaques en 2006), probablement en limitant les taux de récidive. Le taux de récidive a été évalué par le rapport [nombre d’arbres attaqués de nouveau l’année N+1/ nombre d’arbres attaqués l’année N]. La tendance est très intéressante, en effet sur le témoin le taux de récidive est supérieur à 50%, il est de 20% pour la modalité Arbopast, et de 0% pour la modalité Arbopast + Decis. Les différences ne sont cependant pas significatives : la puissance des tests est très faible dans la mesure où nous ne disposons que de 4 attaques jusqu’en 2005 pour estimer le taux de récidive de la modalité Arbopast + Decis (17 pour le témoin, et 6 pour la modalité arbopast). Les dégâts plus nombreux observés en 2006 augmenteront considérablement le nombre de couples disponibles à la notation 2007, et risquent de modifier radicalement cette estimation. Signalons l’importance capitale du taux de récidive : un arbre en pleine production ne souffre pas énormément d’une attaque de cossus. Ce sont les attaques successives et l’augmentation
du nombre de larves qui entrainent jusqu’à la mortalité. Cela semble à ce jour en faveur des méthodes de lutte que nous proposons.

Figure 2. Arbopast: efficacité dans la réduction des dégâts liés au *Cossus*.

**Discussion sur le positionnement des traitements :**

Sur un plan purement technique, il nous semblait important de réaliser cette protection préventive de manière à couvrir en une seule application la plus grande partie de la période d’exposition au ravageur. Au vu des périodes de vol et des incubations supposées, le stade petit fruit semblait le meilleur positionnement technique. La présence potentielle de quelques gouttelettes blanches sur les fruits du haut des arbres nous a obligé à repositionner provisoirement les traitements en post récolte, sans quoi le dossier d’AMM aurait nécessité un « dossier résidus » complet. Dans la mesure où l’usage n’était pas pourvu, il nous semblait essentiel d’aller vite, afin d’offrir au plus tôt une solution aux producteurs en difficulté. Aussi, les applications en 2005 et 2006 ont été réalisées juste après récolte. A cette date, on peut supposer que si la majorité des pontes et des éclosions n’a pas encore eu lieu, un petit nombre de dégâts a déjà pu se mettre en place. Autre point à signaler, nous avons remplacé en 2005 et 2006 Decis CE par Decis Protech, l’utilisation de la matière active microencapsulée a pu changer sa diffusion au travers de la base vinilique d’Arbopast. Cela est peu probable vu les tests de persistance réalisés avec Decis Protech que la société Protecta nous a transmis. L’inflexion des résultats 2006 nous incite en tout cas à la prudence. Il est clair qu’il faudrait dans l’avenir travailler à un meilleur cadrage des dates d’interventions et, si le traitement est nécessaire en présence de jeunes fruits, obtenir des données toxicologiques. Enfin, si les résultats sont significatifs en faveur des méthodes de lutte que nous avons expérimentées, n’oublions pas qu’ils n’ont été obtenus que sur une seule parcelle, et donc, finalement, nos conclusions ont tout de même 5 chances sur 100 d’être erronées (risque de première espèce). Il nous paraît maintenant opportun de passer à une phase en petites parcelles conduites par les producteurs.
Coût et justification technique
Si nous avons appliqué au pinceau le badigeon lors des premiers tests, une application plus diluée à la lance est plus réaliste, et divise par trois le temps d’application. Le temps de travail pour une parcelle jeune est relativement limité et assure un état sanitaire irréprochable tant du point de vue des bactérioses que des insectes ravageurs du bois, c’est un investissement qui permet de démarrer un verger dans de bonnes conditions. Sur un verger en pleine production, il est clair que les temps de travaux ne justifient pas une protection préventive complète des parcelles s’il n’y a pas de symptômes. Par contre, dans une parcelle atteinte et ayant une valeur commerciale, sachant que ce type de protection par badigeon est susceptible d’enrayer la progression du ravageur dans le verger, il faut l’envisager sérieusement d’un point de vue technico-économique.

Conclusion
Dans l’immédiat, notre travail a débouché sur l’autorisation de mise sur le marché d’Arbopast pour l’usage «traitements généraux, traitement des parties aériennes, Zeuzère et Cossus». Nous rappelons ici que l’association Decis/Arbopast n’est à ce jour pas autorisée sur l’usage Cossus. S’il y a encore beaucoup à faire pour disposer d’une méthode de lutte très efficace contre le cossus, les producteurs connaissant de grosses difficultés liées à ce ravageur ont désormais une solution qui présente d’autres avantages (prévention des bactérioses et d’autres attaques de certains insectes et champignons). Les études pourraient aujourd’hui s’orienter vers un badigeon utilisant d’autres matières actives que l’on sait très persistantes, ayant une efficacité reconnue sur des lépidoptères, et dont le profil toxicologique nous permettrait facilement un positionnement à diverses périodes, je pense par exemple au thiaclopride. Cette technique de lutte pourrait aussi présenter un intérêt contre d’autres ravageurs (comme la Sésie). Le caractère pluriannuel des essais, la difficulté de trouver des parcelles adaptées, les temps de travaux importants, constituent cependant un frein sérieux à l’étude de ce type de ravageurs.

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    André Lequet, qui a consacré de son temps en relecture.
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Références bibliographiques
Western Flower Thrips on peach: development of a risk assessment model for optimal chemical control

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Abstract: Western Flower Thrips populations are difficult to control with chemical methods, which leads to severe damage on peaches. These insecticides are not effective on eggs, newly emerged larvae or nympha. Timely application of insecticides is important so that an optimal number of adults are treated, preferably before egg-laying. A climate model for decision making is currently being validated. In 2006, over twenty trials were carried out on a large scale with the help of many collaborators. Analysis of several of these trials has shown the importance of timing on the efficacy of treatment. Slightly better results were obtained when treatments were carried out during the period when the model indicated that nymphs and adults were present simultaneously. Reducing insect populations early in the season is more effective than prior to harvest; this is true for both products registered in France.

Keywords: Modelling, crop protection, experimentation, insect pest, Western Flower thrips

Introduction

The Western Flower thrips (*Frankliniella occidentalis* Perg.) is a small insect from America and has been present in Europe since 1983 and in France since 1986. It is found on a wide range of plants, herbaceous and arborescent, which makes it a very common pest that seems unfamiliar only because of its small size. As soon as it appeared, it spread rapidly and the damage it caused on floral and vegetable crops was easily noticeable. On peach, populations grow on new shoots as well as on fruit nearing maturity. However damage is only caused on fruit. Presence of the pest on new shoots does not affect their development, but their movement to fruit can have serious consequences on fruit quality. On peaches thrips cause silvery scarring on the fruit surface which is purely cosmetic but if severe can lead to a reduction in commercial value of the crop, even though internal fruit quality is not affected. It is important to note that the acceptance or refusal of a batch of fruit is highly dependant on market demand. In 2006, for example, high thrips populations and many damaged fruit characterized the market. But as time went by, high sales during the period of severe thrips damage (end of June, beginning of July) limited the negative effects, which would have been more severe if sales had slumped. Unfortunately no indication exists on future market demand, so growers cannot evaluate the risk involved in reducing crop protection in orchards. Which means that in plots that are regularly attacked control is indispensable to limit damage.

* In collaboration with Centrex, Serfel, Sefra and growers in the Gard and the Bouches-du-Rhône
Western Flower thrips is one of the most difficult pests to control. Effectiveness of treatments is only ever partial and extremely variable. This is probably due to biological particularities of the insect. Firstly the wide host range of plants in the environment and its presence in the environment gives it the opportunity to rapidly return to the crop. Then the egg laying that takes place in the leaves, the young larvae that reside in the tightly folded leaves, the nymphs that fall to the ground, all mean that the insect avoids contact with chemical treatment for the majority of its life cycle. Only the adults and older nymphs that are mobile are vulnerable to treatments. In theory chemical control effectiveness can be improved by judicious timing of treatments.

Materials and methods

The model presented here, developed by the Ctifl, is to aid growers in decision making so that the optimal time of chemical treatment can be determined to improve effectiveness against Western Flower Thrips, and in doing so limit the number of applications.

This event model deals with the sequence of developmental stages of the insect and the generations during one season. It was created using information provided by the many studies carried out in laboratories on the conditions necessary for the development of this species. The parameters were then adjusted based on observations in peach orchards made during several years under various weather conditions.

The model functions using weather data provided by weather stations, which can be automatic if the weather stations are linked up to the Celsius Network. It starts off making a curve that represents the emergence of overwintering nymphs and adults (figure 1). As soon as conditions are favourable for the latter to lay eggs, the model creates a curve to represent the following generation. Each stage of the insect’s life cycle (egg, newly emerged larvae, older larvae, pre-pupae, pupae and adult) is represented on the curve. Then when the adults are ready to lay, the curve of the next generation begins. Throughout the season the successive generations are presented G1, G2, G3..... Obviously in practice things are not as distinct as the model calculates, as two generations may overlap, and it is likely that towards the end of the season the model becomes less accurate.

However, we have been able to show in various trials, that the indications obtained with the model at the beginning of the season provide an important aid in decision making for chemical control programs in the orchard.

Results

It is currently accepted that it is advisable to limit the number of thrips when populations first peak at the end of May/beginning of June (G1). In the south-west of France (on the Crau Plain), this period corresponds to the drying of the sward where thrips are present, encouraging the adults to migrate to the peach trees that are irrigated. It is also important to reduce insect populations before they move onto the fruit. Monitoring is usually carried out by beating the shoots or by installing blue sticky card traps and scouting, once or twice a week, is necessary from the 15th May. Figure 2 shows a good correlation between the figures calculated by the model and the results obtained by trapping in 3 orchards in the Costières du Gard region in 2007, at least for the 1st and 2nd generations. The first part of the curve in green correlates well with the first trappings and the peak in populations is centred on where the adults of one generation and the larvae of the following generation are positioned on the graph. Models using weather forecasts are able therefore to predict events and allow decisions to be made. It is important to note that the model does not give quantitative information.
Information that is provided may be useful in determining the risk period but scouting needs to be carried out to evaluate insect populations more precisely. On the graph one can see for example, that the Diamond Bright plot reveals lower thrips populations than the other plots. The model can indicate when applying control measures will be most effective, but cannot indicate if treatment is necessary in a given plot.

Concerning timing of treatments, close observation of the curves created by the model reveal something of great interest that needs to be studied.

It can be seen that the presence of adults from one generation (G1 for example) and the larvae of the following generation (G2) is simultaneous, which occurs throughout the season. This is of great interest as these two stages of the thrips life cycle are the most vulnerable to chemical applications. Chemical control measures therefore, are most effective if applied during this period.

Trials have been carried out within a network to determine if application at this time would be effective as a control measure.

For the trials two strategies were compared:

- Strategy 1: optimal timing of treatment during the presence of adults and larvae as advised by the model.
- Strategy 2: different timing of treatment during the presence of eggs and pupae, theoretically reducing the efficacy of chemical control.

The trials were carried out on a large plot, that’s to say 4 whole rows per strategy. This trial was carried out in 7 orchards. Variance analysis was used to analyse the damage: each orchard was considered as a statistical repetition in the trial as a whole. The results revealed a significant difference between the two strategies: with strategy 1 there were 10 % less fruit with spots larger than 1 cm². These results are in no way spectacular but they illustrate that timing during this period provides better control.

This model, however, can be useful in another way. Visualizing successive generations of thrips enables growers to reason chemical control measures and adapt them to the maturity of each variety.

In figures 3 and 5 it can be seen that depending on harvest date, fruit can be infested by 1 or 2 thrips generations. If we assume that the optimum spraying time is during the period in strategy 1 and that only one treatment can be applied, then this model may aid in deciding when to treat taking into account the different dates of maturity. To illustrate this, examples of control strategies have been compared in validation trials carried out in 2006.

Figure 3 shows the example of an early variety receiving one treatment when the 1st generation adults and 2nd generation larvae are present. Two strategies were compared: at the beginning and in the middle of this period. The damage observed on fruit was similar, but slightly lower with the treatment applied in the middle of the period.

Figure 4 shows results from an orchard in which 3 strategies were compared:

- Strategy 1: 2 treatments, centred on the 1st and 2nd thrips generations.
- Strategy 2: 1 treatment applied 8 to 10 days before harvest, the conventional control measure carried out by growers.
- Strategy 3: 1 treatment applied on the 2nd thrips generation.

Observations on fruit damage revealed that in this orchard the 1st strategy was most effective. With only 1 treatment, the 3rd strategy gave better results than the 3rd. These results can be explained in 2 ways. The first is that thrips populations were very high in this orchard early on in the season: 156 F. occidentalis adults for 100 shoots on 18th May, just before treatment in strategy 1. The second explanation is that the treatments in strategy 2 and 3 were applied too late, and that the insects had already caused feeding damage to the fruit.
Figure 5 represents a much later variety, Capucine, harvested from 31 July till 7 August in a trial carried out on a farm on the Crau Plain. We can see that there are 5 thrips generations against which control, measures can be taken before the beginning of harvest. Two strategies were compared on this variety in 2 adjacent plots:

- Strategy 1: 2 treatments, on the 1st and 3rd generations
- Strategy 2: 2 treatments, on the 2nd and 4th generations

Observations on fruit damage show that the 2nd strategy was most effective, as the treatments were applied nearest to harvest, the second application coinciding with the generation that precedes the one prior to the one that migrates to fruit. The level of damage with strategy 2 was acceptable, even though population numbers were high. The scouting curves on thrips numbers on shoots show that both plots had similar numbers. There was on average 1 thrips per shoot on 23rd May from the first generation before the 1st treatment. The maximum number of thrips was reached on 28th June during the 3rd generation, with an average of 6 thrips per shoot.

Figure 1 – Model simulation of thrips population development

**Discussion**

These examples illustrate how the information provided by the forecast model can help reason chemical control against Western Flower thrips.

This model is without a doubt a decision-making tool, but it cannot be expected to solve all the problems related to this difficult pest to control. Here are some of the limiting aspects of the model:

- Quality application of the treatment is reliant on spraying material being calibrated and weather conditions adequate. The efficacy of treatment will not be improved if there is wind to reduce penetration into the canopy, especially at the top of the tree. It’s better to delay spraying than to spray when the conditions are unfavourable.
Figure 2 – Comparison of thrips captures and model simulation

Figure 3 – Trial carried out on an early variety
Figure 4 – Trial using 1 or 2 applications in an orchard with high thrips populations

Figure 5 – Trial carried out on a later variety

- Agronomic and environmental conditions directly influence thrips movement to fruit. Insects remain on shoots until growth ceases when they move onto fruit. This happens naturally during the last growth stage of the fruit when they become more attractive to the pests. It intensifies when the weather gets warmer, when water is scarce or when fruit load is in excess. The same happens for pests on plants in and around the orchard. The thrips move naturally onto trees and then fruit when they become more attractive. The grass sward can increase this risk if it dries out or if mowing is delayed.
- Certain varieties are more attractive to these pests (fruit with smooth skin), others show discoloration more easily (uniform intense red colour).
We would like to conclude in saying that the aim of this work was to improve chemical control efficacy based on the two products currently registered (Orytis, Success 4). These two substances are to be used with restraint and in alternation to avoid the development of resistance, as this insect has already developed resistance to several other products. Good control of this pest based on one or two applications should provide sustainable control. Follow up work will be based on studying different control strategies combining the utilization of these products depending on ripening dates as well as their efficacy against other pest for which they are also registered (oriental fruit moth, peach twig borer).

References

Dynamics and control of *Lygus rugulipennis* Poppius in peach orchards of NW Italy

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² CReSO – Consorzio di Ricerca Sperimentazione e Divulgazione per l’Ortofrutticoltura Piemontese, corso Nizza 21, 12100 Cuneo, Italy

Abstract: Since the ‘90s, damage to fruits due to the European tarnished plant bug, *Lygus rugulipennis* Poppius (Heteroptera: Miridae), has been recorded in peach orchards of Piedmont (North-West Italy). Investigations carried out in 1992-1994 showed that an accurate weed management in the orchards, i.e. mowing of alternate rows, prevented the plant bugs from migrating to peach trees. However, recently severe damage to peach has been reported also in well-managed orchards, so research has been carried out in 2004-2006 to assess seasonal abundance and movement of *L. rugulipennis* inside and outside orchards and to evaluate the efficacy of some insecticides commonly used in IPM to control other peach pests. Field surveys confirmed that the plant bug generally lives and reproduces on herbaceous plants, and migrates onto peach trees when winter cereals are harvested and usual host plants are lacking. Overall, in the investigated orchards, damage to peach fruits never exceeded 10%, and was mainly localized on trees in external rows near cereal crops. Among the active ingredients (etofenprox, malathion, spinosad, thiacloprid) tested in laboratory and semifield trials, malathion was the most efficient in controlling *L. rugulipennis* adults.

Key words: European tarnished plant bug, Heteroptera Miridae, field surveys, damage, control trials

Introduction

Since the ‘90s, severe injuries to fruits due to bug feeding have been reported in several peach orchards of Piedmont (North West Italy). Previous investigations showed that the most abundant and noxious species was the European tarnished plant bug, *Lygus rugulipennis* Poppius (Heteroptera: Miridae) (Tavella et al., 1994, 1997), already recorded for damage to peach in other Italian regions (Cravedi & Carli, 1987a, Cravedi & Carli, 1987b). The plant bug is widespread throughout the palearctic region, it can live and develop on a large host range but it prefers herbaceous plants belonging to Fabaceae, Asteraceae, and Brassicaceae (Holopainen & Varis, 1991).

In NW Italy, *L. rugulipennis* accomplishes 3-4 generations a year, overwintering as adults. In spring adults leave winter shelters and migrate mainly to winter cereals, where females start to oviposit. In June, newly emerged adults of the 1st generation move from ripening cereals to other host plants, among which the weeds in peach orchards (Rancati et al., 1996, Tavella et al., 1997). Research carried out in 1992-1994 showed that an accurate weed management in the orchards, i.e. mowing of alternate rows, prevented the plant bugs from migrating to peach trees (Tavella et al., 1996).

However, recently severe damage to peach has been reported also in well-managed orchards, so research has been carried out in 2004-2006 to assess seasonal abundance and movement of *L. rugulipennis* inside and outside orchards, and to evaluate the efficacy of some insecticides commonly used in IPM to control other peach pests.
Materials and methods

Population dynamics of *L. rugulipennis* in peach agroecosystems of NW Italy

Field surveys were carried out in the 3-year period, 2004-2006. *L. rugulipennis* populations were periodically monitored in peach orchards, in which severe damage by bugs was previously recorded, and in the neighbouring crops. Sampling was effected using a sweep net on weeds in the orchards, winter cereals, alfalfa, and beating the vegetation over a white canvas on peach, actinidia, green bean, maize. In 2004 and 2005, yellow and blue sticky traps were used to monitor movements of plant bug adults inside and outside the orchards. During each survey 250 fruits were checked from late May to harvest to detect any symptoms. At harvest at least 1,500 fruits per orchard were examined to assess damage levels.

Chemical control of *L. rugulipennis*

Laboratory and semifield trials were carried out to evaluate the direct toxicity and the persistence of 4 active ingredients (a.i.) (malathion, etofenprox, spinosad, thiacloprid) commonly used in IPM programmes in peach orchards.

The direct toxicity was evaluated in the laboratory using glass vial bioassays described by Snodgrass (1996). Adults of *L. rugulipennis* were introduced into 45-ml glass vials (3 adults per vial) previously treated with the insecticide being tested at the label rate. The a.i. was applied by pipetting 1 ml of solution into each glass vial, that was rolled until an even layer of insecticide dried on its inner surface. A green bean pod was then added into each vial as food for adults. All bioassays were conducted in climatic chambers at temperature 25±1°C and relative humidity 70±5%.

Semifield trials were carried out in peach orchards in Lagnasco (province of Cuneo, NW Italy), in 2005 and 2006. Net cages were placed on branches having fruits, previously treated with the insecticides being tested at the label rate; then 5 adults of *L. rugulipennis* were introduced into each cage and checked after 48 hours to assess their mortality. Moreover, in 2005 the persistence of the 4 a.i. was evaluated introducing 5 adults per cage one week after the treatment.

Results and discussion

Population dynamics of *L. rugulipennis* in peach agroecosystems of NW Italy

Population levels were variable in the investigated orchards in the 3-year period; however plant bugs were collected on weeds rather than on peach (Figure 1), and in greater amounts on weeds in the rows neighbouring to winter cereals starting from late June. First symptoms on fruits were observed starting from late May. At harvest the percentage of injured fruits was variable, but always under 8% also in those orchards where in previous years damage exceeded 30%. Among other surveyed crops, large amounts of *L. rugulipennis* were observed on winter cereals until nearly-ripening, and also on alfalfa, green bean and maize. Both yellow and blue sticky traps captured no one or few plant bug adults not allowing to monitor their movements inside and outside orchards.

Field surveys confirmed that *L. rugulipennis* prefers herbaceous plants, but in their absence it can migrate to arboreous plants, such as peach tree, and so cause damage to fruits (Cravedi & Carli, 1987a, Tavella *et al.*, 1997). Plant bug populations increase in the peach orchards starting from late June, in further confirmation that *L. rugulipennis* completes the 1st generation on nearly-ripe winter cereals, then it moves to other neighbouring crops. The treatments with pyrethroids to control cereal bugs on wheat seem to reduce only temporarily the plant bug populations.
Severe damage recently reported also in well-managed orchards can be due to different factors, among which neighbouring crops and climatic conditions. In fact, plant bug attacks were more severe in orchards adjoining winter cereals and in summers characterized by warm and dry weather, favourable to outbreaks of *L. rugulipennis* and unfavourable to herbaceous vigour. Moreover, early ripening nectarines, such as cultivar Big Top, now widespread in our region, are very susceptible to the bug feeding activity, which causes sometimes deep, crater hollows, never associated with gummosis.

**Chemical control of *L. rugulipennis***

The results of the laboratory trials are reported in Table 1. Among the a.i. tested in the bioassays, etofenprox and malathion determined a high mortality, whereas spinosad and thiacloprid did not show any efficacy against *L. rugulipennis*. In particular, etofenprox with the two products Trebon and Trebon Star caused different mortality rates, however consistent with the values obtained in a dipping experiment (Iwasaki, 2001).

<table>
<thead>
<tr>
<th>Active ingredient</th>
<th>Trade name</th>
<th>Label rate (ml/hl)</th>
<th>Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malathion</td>
<td>Smart EW (Cheminova)</td>
<td>250</td>
<td>93</td>
</tr>
<tr>
<td>Etofenprox</td>
<td>Trebon (Sipcam)</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Etofenprox</td>
<td>Trebon Star (Sipcam)</td>
<td>100</td>
<td>87</td>
</tr>
<tr>
<td>Spinosad</td>
<td>Laser (Dow AgroSciences)</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>Thiacloprid</td>
<td>Calypso (Bayer CropScience)</td>
<td>25</td>
<td>0</td>
</tr>
</tbody>
</table>

In semifield trials, mortality rates were lower than those ones assessed in laboratory trials, and variable in the 3 replications (Table 2). In 2005 both etofenprox and malathion
determined a higher mortality of \textit{L. rugulipennis}, whereas in 2006 only malathion was effective in controlling plant bug adults. Anyway, the efficacy of both etofenprox and malathion was strongly reduced when the insects were introduced in the cages one week after the treatment.

Table 2. Mortality of \textit{Lygus rugulipennis} Poppius assessed in semifield trials. Values were corrected for control mortality according to Abbott’s formula.

<table>
<thead>
<tr>
<th>A.i.</th>
<th>Trade name</th>
<th>Label rate (ml/hl)</th>
<th>Mortality (%)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1\textsuperscript{st} trial (2005)</td>
<td>2\textsuperscript{nd} trial (2005)</td>
<td>3\textsuperscript{rd} trial (2006)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0\textsubscript{t0}</td>
<td>0\textsubscript{t1}</td>
<td>0\textsubscript{t0}</td>
<td>0\textsubscript{t1}</td>
</tr>
<tr>
<td>Malathion</td>
<td>Smart EW (Cheminova)</td>
<td>250</td>
<td>45.7</td>
<td>10.3</td>
<td>36.7</td>
<td>3.1</td>
</tr>
<tr>
<td>Etofenprox</td>
<td>Trebon (Sipcam)</td>
<td>50</td>
<td>60.0</td>
<td>31.0</td>
<td>40.0</td>
<td>15.6</td>
</tr>
<tr>
<td>Etofenprox</td>
<td>Trebon Star (Sipcam)</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Spinosad</td>
<td>Laser (Dow AgroSciences)</td>
<td>25</td>
<td>5.7</td>
<td>6.9</td>
<td>26.7</td>
<td>12.5</td>
</tr>
<tr>
<td>Thiacloprid</td>
<td>Calypso (Bayer CropScience)</td>
<td>25</td>
<td>22.9</td>
<td>13.8</td>
<td>13.3</td>
<td>6.3</td>
</tr>
</tbody>
</table>

\* 0\textsubscript{t0} = insect introduction immediately after treatment.
\** 0\textsubscript{t1} = insect introduction one week after treatment.

Overall, in both laboratory and semifield conditions the most effective a.i. against \textit{L. rugulipennis} was malathion, which reduced significantly populations of other plant bugs in trials carried out on birdsfoot trefoil in North America (Wipfli \textit{et al.}, 1990). By contrast, etofenprox showed different toxicity levels in relation to the commercial product, so further investigations are required to evaluate its actual efficacy in controlling plant bug infestations.

**Acknowledgements**

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**References**


A survey on cherry organic production in Italy

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2 Associazione Italiana per l’Agricoltura Biologica (AIAB), via Piave, 14, 00187 Roma, Italy

Abstract: The Fruit Growing Institute of Piacenza and AIAB are carrying on a survey on the main characteristics of the Italian organic cherry cultivation. The information requested to 267 organic cherry growers regard: farm location and cherry orchard description; management and protection practices; harvesting and commercial organization; problems and opinion on biological cherry’s cultivation. The information up to now available evidenced the heavy incidence of Ceratitis capitata and Monilia damages as phytosanitary problems, the difficulty to find adequate workers for the harvesting period and a little consumer’s interest about biological cherries and so scarce remuneration for this product.

Key words: farmer survey, organic management, sweet cherry.

Introduction

During the last years in Italy the organic cherry production has spread, but the problems for this cultivation are not clearly known. The Fruit Growing Institute of Piacenza in addition to investigate the fruit quality of organic cherries (Ughini et al., 2006) has wanted to acquire the experience and opinion of Italian cherry organic farmers. With this aim it have devised with AIAB (Associazione Italiana per l’Agricoltura Biologica) a schedule for the cherry growers that belong to the just mentioned association.

Material and methods

267 cherry growers, mainly of which jointed to AIAB, were contacted and their regional distribution (as percentage) is shown in Table 1. It is interesting to remark that this distribution well represents the regional distribution of cherry production in 2005 which is reported in Figure 1 that is made after the elaboration of data by Istat (Istituto Nazionale di Statistica).

For each grower the following information were requested:
– location, climatic and soil characteristics of the orchard;
– cherry orchard description;
– cultural practices and pest and disease management;
– harvest, fruit manipulation and destination;
– problems for cultivation, harvest and fruit destination;
– personal opinions on the convenience of organic cherry production.
Results and discussion

The survey is still in progress and for the larger cherry organic growers it is also planned a field visit. Nevertheless preliminary results concerning the answers up to now received show the following principal aspects:

- the biological adversity more spread is *Rhagoletis cerasi* (for up to 80% of the growers) but also *Monilia*, aphids and *Coryneum* are signalled by many growers.
- also for this cultivation management during the harvest season it is difficult to find workers.
- the consumer is poorly interested in the organic cherries so their prices yield no profit.
- the organic cherry grower opinion is satisfactory from an economic and agronomic point of views, whilst the organic cherry cultivation is considered discrete or sufficient for the productivity.

Table 1. Regional distribution of 267 cherry organic growers contacted for the survey.

<table>
<thead>
<tr>
<th>Regions</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Puglia</td>
<td>30.4</td>
</tr>
<tr>
<td>Emilia Romagna</td>
<td>29.6</td>
</tr>
<tr>
<td>Veneto</td>
<td>8.2</td>
</tr>
<tr>
<td>Lazio</td>
<td>6.7</td>
</tr>
<tr>
<td>Abruzzo</td>
<td>5.2</td>
</tr>
<tr>
<td>Campania</td>
<td>3.4</td>
</tr>
<tr>
<td>Lombardia</td>
<td>3.0</td>
</tr>
<tr>
<td>Piemonte</td>
<td>3.0</td>
</tr>
<tr>
<td>Toscana</td>
<td>3.0</td>
</tr>
<tr>
<td>Basilicata</td>
<td>2.6</td>
</tr>
<tr>
<td>Calabria</td>
<td>1.9</td>
</tr>
<tr>
<td>Umbria</td>
<td>1.9</td>
</tr>
<tr>
<td>Liguria</td>
<td>.7</td>
</tr>
<tr>
<td>Sicilia</td>
<td>.4</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Acknowledgements

We want to thank Dr. Antonio Monteforte, Dr. Claudio Plessi and Dr. Gian Luca Malvicini for the help in field survey.

References

Market quality of cherries from organic management ♦

Ughini V., Roversi A., Malvicini G.L.
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Abstract: With the aim to outline consumer trends and preference the marketable quality of cherries obtained under organic production system was investigated. This paper reports the results of the evaluation of marketable visual parameters of 6 cultivars grown either under organic and conventional system, made by a trained panel. The non parametric statistic elaboration of the data had evidenced for some parameters positive (e.g. for brightness and shape) or negative (e.g. skin colour ) or no different evaluation of “organic cherries” when compared with the conventional one.

Key words: visual fruit evaluation, organic sweet cherries, conventional sweet cherries,

Introduction

If italian investigations on organic cherry production are really scarce, those concerning their marketable quality are even absent.

So, with the aim to investigate consumer trend and preference for cherries obtained under organic orchard management, previously their commercial quality was assessed for visual traits which plays an important role in consumer acceptance (Crisosto et al, 2003) and could address consumer purchases.

Material and methods

Investigations were carried on 6 sweet cherry varieties grown in the experimental field established by the Vignola Municipality (Modena). The field is made up by 2 properly separated parts of which one managed with organic protocol (=ORG) whilst the other with conventional protocol (= CON).

All trees of all cultivar (Anellone, Cristallina, Kordia, Ferrovia, Regina e Sweet Heart) of all kind of management here considered were grafted onto Colt, and for 2 of them (Regina and Sweetheart) trees were also grafted onto MaxMa 14.

At the harvest time of each cultivar, that is on June 19th and 26th and on July 5th (when the solid soluble concentration was at least 17%), for each combination rootstock and orchard management, 2-3 kilograms of cherries were picked off from the fruiting belt between 1,5 and 3 meters above the soil level and from every crown orientations. These samples of fruits not graded (“scendialbero”)were kept at 10-12°C for 12-24 hours before their organoleptic evaluation made in the proper panel room of the Istituto di Fruttiviticoltura of Piacenza. In particular for Ferrovia and Kordia, comparisons were also made between samples of not graded and graded cherries the last obtained after a fruit selection for skin colour, fruit size and integrity (see the CE regolamento 214/2004).

The organoleptic evaluations were made by a panel of 9 judges choosen among 19 people for their ability to distinguish the 4 fundamental tastes and previously trained on the marketable quality of cherry as reported in the above mentioned Regolamento CE. For these

♦ Investigation financially supported by ORTOFRUBIO-MIPA Project.
evaluations the panel was requested to quantify the intensity of some visual (e.g. stem freshness, skin brightness) and gustative parameters (consistency, juiciness, acidity, sweet-ness, bitterness, aromatic and in particular bitter almond aroma and mouth stone perception) and the “acceptance” of others visual parameters (skin colour and fruit size and shape). For each parameters and sample, each panelist attributed a score ranging from 1 (very low) to 10 (highest) following a particular procedure for the evaluation.

The statistical analysis compared the average value of each organoleptic parameter between the 2 kind of management by the Mann–Withney non parametric test.

As previously said, this paper reports the results concerning the visual parameters that are likely adopted when cherries are purchased.

**Results and discussion**

Here with the comparison between the 2 orchard management evidences for each parameter the following results.

**Stem Freshness**

When all the cultivar are considered (Table 1), the cherries yielded in the conventional system are better evaluated (7.16) than those from organic (7.03).

Also the cherries from trees grafted onto MaxMa 14 are greater evaluated (Table 2) if from conventional management (7.30 vs. 7.28). On the contrary a better appearance is assessed to the organic cherries on Colt (7.85 vs. 7.53).

A better appearance of the stem freshness is for conventional production (7.15 vs. 6.75) when fruits are not selected (Tab.3) and for organic production when a grading (selection) is made (7.37 vs. 6.90).

Any statistically significance is evidenced for the comparison made for these parameters.

**Skin Colour**

A general preference for the organic cherries (7.55) is resulted (Table 1) when all varieties are considered.

Also the cherries from trees on Colt rootstock and organic management (7.52) are better evaluated (Table 2), whilst for those on MaxMa 14 are preferred those from conventional system (average score of 7.88).

The cherry sample of no graded fruit are preferred (Table 3) when harvested in the orchard managed conventionally (7.60): The contrary when evaluated those selected for which are the preferred the organic one (8.33).

Any for these parameters any comparison is statistically significant.

**Skin brightness (brilliance)**

When all varieties are considered (Table 1) a more intensive brightness (7.24 vs 7.03) is assessed to the fruit from organic management, especially for those of Anellone (p=.005).

Even when rootstock influence is considered the skin brightness of the fruit from organic management is more intensive (Table 2), in particular it is significant (p=.035) the comparison between the 2 kind of orchard management for Sweetheart on MaxMa14.

Also for the graded cherries a better evaluation (8.03) is given to the fruit from the organic system (Table 3) even this it is not confirmed for the sample of fruit not selected sample (7.50 con vs. 7.30 org).

**Fruit Shape**

In general a preference is given to the cherry from organic management (Table 1) and this is also confirmed when the influence of the rootstock is weighted (Table 2), especially for Sweetheart on MaxMa14 (p=.005).
Table 1. Fruit marketable quality of 6 sweet cherry varieties as influenced by orchard management and rootstock.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Stem freshness (a)</th>
<th>Skin colour (b)</th>
<th>Skin brightness (c)</th>
<th>Fruit shape (d)</th>
<th>Fruit size (e)</th>
<th>Sum (a-e)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CON</td>
<td>ORG</td>
<td>p</td>
<td>CON</td>
<td>ORG</td>
<td>p</td>
</tr>
<tr>
<td>Anellone</td>
<td>6.50</td>
<td>7.10</td>
<td>.313</td>
<td>6.82</td>
<td>7.82</td>
<td>.111</td>
</tr>
<tr>
<td>Cristallina</td>
<td>7.10</td>
<td>5.90</td>
<td>.660</td>
<td>8.18</td>
<td>7.82</td>
<td>.616</td>
</tr>
<tr>
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<td>6.70</td>
<td>.471</td>
<td>7.90</td>
<td>8.00</td>
<td>.690</td>
</tr>
<tr>
<td>Ferrovia</td>
<td>7.30</td>
<td>6.80</td>
<td>.436</td>
<td>7.30</td>
<td>6.60</td>
<td>.165</td>
</tr>
<tr>
<td>Regina</td>
<td>8.70</td>
<td>8.60</td>
<td>.579</td>
<td>7.45</td>
<td>7.73</td>
<td>.652</td>
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<tr>
<td>Sweetheart</td>
<td>6.35</td>
<td>7.10</td>
<td>.307</td>
<td>7.20</td>
<td>7.30</td>
<td>.812</td>
</tr>
<tr>
<td>averages</td>
<td>7.16</td>
<td>7.03</td>
<td>.559</td>
<td>7.48</td>
<td>7.55</td>
<td>.955</td>
</tr>
</tbody>
</table>

Table 2. Fruit marketable quality of 2 sweet cherry varieties as influenced by orchard management and rootstock.

<table>
<thead>
<tr>
<th>Root stocks</th>
<th>Cultivar</th>
<th>Stem freshness</th>
<th>Skin colour</th>
<th>Skin brightness</th>
<th>Fruit shape</th>
<th>Fruit size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CON</td>
<td>ORG</td>
<td>p</td>
<td>CON</td>
<td>ORG</td>
<td>p</td>
</tr>
<tr>
<td>Colt</td>
<td>Regina</td>
<td>8.70</td>
<td>.579</td>
<td>7.45</td>
<td>7.73</td>
<td>.652</td>
</tr>
<tr>
<td></td>
<td>Sweetheart</td>
<td>6.35</td>
<td>.307</td>
<td>7.20</td>
<td>7.30</td>
<td>.812</td>
</tr>
<tr>
<td></td>
<td>averages</td>
<td>7.53</td>
<td>.559</td>
<td>7.33</td>
<td>7.52</td>
<td>.955</td>
</tr>
<tr>
<td>MaxMa 14</td>
<td>Regina</td>
<td>8.20</td>
<td>.286</td>
<td>8.45</td>
<td>7.77</td>
<td>.281</td>
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<tr>
<td></td>
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<td>6.40</td>
<td>.353</td>
<td>7.30</td>
<td>7.28</td>
<td>.996</td>
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<tr>
<td></td>
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<td>.992</td>
<td>7.88</td>
<td>7.53</td>
<td>.516</td>
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</table>
Table 3. Fruit marketable quality of 2 sweet cherry varieties as influenced by orchard management and fruit grading for sale.

<table>
<thead>
<tr>
<th>Fruit grading</th>
<th>Cultivar</th>
<th>Stem freshness</th>
<th>Skin colour</th>
<th>Skin brightness</th>
<th>Fruit shape</th>
<th>Fruit size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>con</td>
<td>org</td>
<td>p</td>
<td>con</td>
<td>org</td>
</tr>
<tr>
<td>Yes</td>
<td>Kordia</td>
<td>7.20</td>
<td>7.80</td>
<td>.250</td>
<td>8.10</td>
<td>8.70</td>
</tr>
<tr>
<td></td>
<td>Ferrovia</td>
<td>6.60</td>
<td>6.95</td>
<td>.750</td>
<td>8.30</td>
<td>7.95</td>
</tr>
<tr>
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<td>6.90</td>
<td>7.37</td>
<td>.481</td>
<td>8.20</td>
<td>8.33</td>
</tr>
<tr>
<td>No</td>
<td>Kordia</td>
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<td>6.70</td>
<td>.471</td>
<td>7.90</td>
<td>8.00</td>
</tr>
<tr>
<td></td>
<td>Ferrovia</td>
<td>7.30</td>
<td>6.80</td>
<td>.389</td>
<td>7.30</td>
<td>6.60</td>
</tr>
<tr>
<td></td>
<td>averages</td>
<td>7.15</td>
<td>6.75</td>
<td>.278</td>
<td>7.60</td>
<td>7.30</td>
</tr>
</tbody>
</table>
Whilst the comparison between the 2 kind of orchard management, for fruit graded or not (Table 3) always evidenced a preference for those from conventional system.

**Fruit Size**
A higher score is given to the fruit from the organic system when all the varieties (Table 1) and each rootstock (Table 2) are considered. In particular it is significant the comparison for Sweetheart on MaxMa 14.

A higher score to the cherries from organic management is assessed to the fruit evaluated after grading (Table 3) even if this is not confirmed when the evaluation is made for the sample of cherries not graded (7.45 for CON vs. 7.15 for ORG).

For all the marketable parameters considered the following is evidenced:

- the scores obtained, for all cultivars and for each comparison, are always greater than 5 that is the medium score and a certain preference among cultivar (see the sums of Tab.1) it is evidenced;
- between the sampled cultivars and for all the parameters considered, except stem freshness, fruits growing in organic system has been preferred (Fig.1);
- plants grafted on Colt, a semi dwarf rootstock grown in organic system, in general, provided very appreciated fruits for every commercial parameter. On the other side, plants grafted on MaxMa 14, under organic system, gave fruits more appreciated for brightness, shape and size;
- in general, no graded samples are better evaluated if belong from conventional system. Instead, for the graded sample, those grown under organic system result more appreciated (Fig.2).
- Low significance obtained from all the comparisons, showed how consumer is not able to recognize difference between organic and conventional cherries.

Further investigations will be made using both professional and consumer panels.

![Figure 1](image_url)

Figure 1. Average score for 5 marketable traits of the fruits of 6 sweet cherry cultivar on Colt, as related to orchard management.
Figure 2. Average score for 5 marketable traits of graded fruits of 2 sweet cherry cultivar, as related to orchard management.

References


Crisosto, H.C., Crisosto, G.M. & Metheney, P. 2003: Consumer acceptance of “Brooks” and “Bing” cherries is mainly dependent on fruit SSC and visual skin color. – Postharvest Biology and Technology 28: 159-167.
Common pests in Croatian peach orchards

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Abstract: The main problem in peach production and the other stone-fruit production in Croatia are aphids, Cydia molesta, Anarsia lineatella and Capnodis tenebrionis. Recently many problems on peach fruits have resulted from chafers of the Scarabeidae family, as well as Cetonia aurata and Potosia cuprea. They have damaged fruits after the appearance of mildew. The above-mentioned pests create considerable problems because they appear in orchards in the ripening period. Monitoring these pests is not common in Croatia in comparison to monitoring of key pests by pheromone traps. Monitoring chafers by Csalomon traps in Dalmatia has shown a large population of Cetonia aurata and Potosia cuprea in 2005 and a smaller population in 2006. The capture of chafers by traps as mass trapping could have prevented damage on peach fruits.

Key words: pests, peach, chafers, mass trapping

Introduction

Peach production is mainly located in the Mediterranean part of Croatia. Peach orchards are small and in average range from 0.5 to 2 ha. Peach production is organized on family farms. The main problem in peach production and other stone-fruit production is Capnodis tenebrionis. It results from climate conditions and non-existence of the irrigation system. In addition to key pests on peach Cydia molesta and Anarsia lineatella peach fruits have been damaged recently by other pests untypical for stone fruit (Ciglar et al., 2004). Fauna monitoring in IFP has been organized only on key pests, but some untypical ones can surprise fruit growers and make serious damage. A «new problem» in Croatian peach orchards are the chafers Cetonia aurata L. and Potosia cuprea F. The adult beetles cause damage to ripening peaches. They chew holes and feed on the flesh of the fruit. Mildew appeared on the attacked fruit. Fauna monitoring on peach orchards in middle Dalmatia has shown that the pest from Gryllidae family made damage on fruits.

Materials and methods

Monitoring peach orchards fauna was carried out in Dalmatia, in the vicinity of the city of Zadar and the city of Omis. Except of the beating method that showed to be good for complete fauna, pheromone traps were used for key pests (Cydia molesta, Anarsia lineatella) and special traps for Cetonia aurata. Traps were set up in two peach orchards at a 10 x 15 m grid on the recommendation of Dr. Tóth. Monitoring was carried out in two years: 2005 and 2006.
Results and discussion

During 2005, 692 *Cetonia aurata* and 365 *Potosia cuprea* were captured in the peach orchard of 1 ha in the Zadar area. Only four traps were used during this monitoring. Damage caused by rose chafers on peach fruits was prevented, unlike other orchards in that region.

![Fig. 1 Capture of chafers by traps in the peach orchard in 2005.](image1)

Monitoring of the chafer population in the same orchard in 2006 has shown a lower number of captured pests (only 30 *Cetonia aurata*, and 49 *Potosia cuprea*). *Cetonia aurata* were captured in the period from 27th May to 23rd June. The flight period of *Potosia cuprea*
was longer than the flight period of *Cetonia* sp. It began on 27\textsuperscript{th} May and lasted until 5\textsuperscript{th} September, but the majority of chafers were caught in the first half of July.

**Acknowledgements**

We express our acknowledgments to Dr. Miklos Tóth for pheromone traps that were gratis in the first year of experiment and his suggestions in this investigation.

**References**


Delobel – Pascal, Catherine
*Station d’Expérimentation Fruits Rhône Alpes (SEFRA), 26800 Etoile sur Rhône, France*

Résumé: En France la bactériose (*Pseudomonas* sp.) est l’une des principales causes de mortalité dans les vergers d’abricotiers. Aujourd’hui, la lutte contre cette maladie est essentiellement prophylactique en raison de l’absence de moyens curatifs efficaces. Les connaissances acquises ces dernières années nous ont orientés vers une étude plus approfondie de deux pistes de travail : l’utilisation du porte-greffe Rubira et le recours au greffage haut. Ces deux techniques ont confirmé largement leur intérêt par la moindre sensibilité à la bactériose qu’elles confèrent, tout en assurant un comportement agronomique satisfaisant. Néanmoins une légère augmentation de la densité de plantation s’avère être nécessaire afin de garantir le rendement à l’hectare.

Mots clés: *Pseudomonas* spp., mesures prophylactiques, Rubira, greffage haut.

Introduction

La bactériose de l’abricotier ou chancre bactérien est une maladie épisodique, qui peut être selon les années et les bassins de culture de l’abricotier, la principale cause de mortalité dans les vergers. En France, elle est présente dans toutes les zones de production : Ardèche, Drôme, Gard et Pyrénées Orientales.

La maladie est causée par plusieurs bactéries qui appartiennent au genre *Pseudomonas* (*P. syringae* pv *syringae*, *P. syringae* pv *morsprunorum* et *P. viridiflava*). Le cycle de développement présente une phase épiphyte où les bactéries survivent tout l’été à la surface des feuilles sans gêne apparente pour l’arbre. La pénétration bactérienne s’effectue à la faveur des blessures naturelles comme l’écartement des écailles des bourgeons et les microlésions liées au gel, ou accidentelles comme les plaies de taille. Les symptômes sont divers et ils vont des simples écoulements gommeux jusqu’à la formation des chancres sur les charpentières et tronc pouvant provoquer la mort de l’arbre. Les dégâts sont la conséquence directe d’une forte densité bactérienne dans les tissus, de leur pouvoir glaçogène et des basses températures. En effet, elles peuvent induire la formation de cristaux de glace dans les tissus de la plante à des températures entre – 2 à – 3°C au lieu de – 7°C (Edin, 2000).

Afin de comprendre la biologie des espèces bactériennes impliquées et de définir des stratégies de lutte, plusieurs études ont été entreprises en collaboration avec l’INRA, les Chambres d’Agriculture et les Stations Régionales.

Ces études nous permettent de préconiser aujourd’hui une série de mesures prophylactiques à même de réduire l’impact de la maladie. Rappelons qu’à présent aucune méthode curative n’est disponible. Les mesures prophylactiques préconisées sont les suivantes:

1. Proscrire les parcelles trop gélives et les bas fonds (zones les plus froides).
2. Eviter de planter sur des sols acides et déficients en calcium; ainsi que sur des sols à texture grossière. Les sols caillouteux favorisent le stress hydrique en été (mauvaise alimentation calcique), et une forte hydratation de l’arbre en hiver (meilleure diffusion bactérienne dans les tissus).
3. Bien choisir l’association variété/porte-greffe, autant pour son adaptabilité au sol que pour son comportement face à la bactériose.

4. Effectuer la taille des arbres en deux étapes : une première taille précoce (mi-juillet à mi-aôut) qui sera complétée par une taille tardive à partir de mars, afin de limiter au maximum toute intervention d’octobre à février, moment où les risques d’attaque (faible cicatrisation des plaies) se trouvent à leur maximum. La désinfection des sécateurs à l’alcool est importante surtout en verger contaminé.

5. Pratiquer une irrigation et une fertilisation modérées et régulières. Le nettoyage du rang et de l’entre-rang sont importants car les gels sont souvent plus forts sur des hautes couvertures végétales.

6. Nettoyer le tronc et la base des charpentières (tous rameaux et brindilles) en été ainsi qu’appliquer un bâton de cuivre à base de cuivre, dès la mi-aôut à mi-septembre avant l’arrivée des pluies automnales.

Après ce bref rappel des connaissances acquises ces dernières années, cet article présente les derniers résultats sur deux sujets d’étude:

1) le comportement agronomique et sanitaire du greffage haut (120 cm).


2) le comportement agronomique et sanitaire du porte-greffe Rubira.

   Des essais porte-greffe implantés en Ardèche sur des sols légers dans les années 90 ont montré que des abricotiers (Bergeron) greffés sur Rubira étaient voir d’une meilleure résistance à la bactériose en comparaison à plusieurs porte-greffe pêchers et au franc d’Abricotier (Edin et al., 2000). Néanmoins, peu de références existaient sur le comportement du porte-greffe Rubira avec d’autres variétés et dans d’autres situations pédoclimatiques. Ainsi, deux essais porte-greffe avec une gamme variétale ont été implantés.

Matériels et méthodes

Le greffage haut : comportement agronomique et incidence sur la bactériose

- Nombre et localisation des essais: 8 parcelles: Ardèche (3), Drôme (4) et Gard (1).
- Date de plantation: 1998
- Variétés: Bergeron, Early blush® Rutbhart (cov), Orangered® Bhart (cov).
- Porte-greffe: Manicot GF1236, Montclar® Pêcher Franc Chanturgue, Pêcher Franc Rubira, P2315, Myrobalan B.
- Nombre de répétitions: minimum 6 arbres par modalité.
- Hauteurs de greffage: 20 cm, 60 cm et 120 cm.
- Distances de plantation: variable selon le site; 6 x 4.5m, 6 x 4 m, 5 x 5 m.
- Variables observées: 1) vigueur estimée à partir de la section du tronc en cm² (8 parcelles); 2) expression de la maladie estimée en fin de printemps à partir d’une échelle de notation : 0= arbre sain, 1 = présence de chancres, 2 = une charpentière morte, 3 = deux charpentières mortes, 4 = trois charpentières mortes, 5 = arbre mort, (8 parcelles); 3) Production moyenne en kg/arbre et poids moyen des fruits en grammes (2 parcelles); 4) Temps de travaux (taille, éclaircissage, récolte) en heures/ ha (2 parcelles).
**Comportement agronomique du porte-greffe Rubira**

- Nombre et localisation des essais: 2 parcelles, Drôme et Gard.
- Date de plantation: 1999
- Variétés: Bergarouge® Avirine, Early blush® Rutbhart (cov), Golbar® Toyiba (cov), Goldstrike® Toyesi (cov), Hargrand, Harostar (cov), Harval (cov), Orangered® Bhart (cov), Robada (cov), Tom Cot® Toyaco (cov).
- Porte-greffe: Pêcher Franc GF 305 et Rubira.
- Nombre de répétitions: 6 arbres par modalité.
- Distances de plantation: 6 x 4 m.
- Variables observées: 1) vigueur estimée à partir de la section du tronc en cm²; 2) expression de la maladie estimée en fin de printemps à partir d’une échelle de notation; 3) production moyenne en kg/arbre et poids moyen des fruits en grammes.

**Résultats et discussion**

**Le greffage haut: protection contre la bactériose et comportement agronomique**

**Bactériose:**
Les dégâts occasionnés par la bactériose sont très variables selon les années, les caractéristiques de la parcelle et leur environnement. L’année 2005, année à forte pression bactérienne, nous permet de bien différencier les différentes modalités testées. La figure 1 met en comparaison différents porte-greffe pour une même variété et parcelle. Ainsi et indépendamment de la localisation, du porte-greffe et de la variété, le greffage à 120 cm permet de réduire de moitié les dégâts causés par la maladie. Ces résultats sont constatés chaque année même si le niveau de dégât est faible. Par ailleurs, le porte-greffe Rubira confirme sa moindre sensibilité.

![Figure 1. Incidence du greffage haut sur la bactériose, année 2005.](image)

**Vigueur:**
En ce qui concerne la vigueur des arbres (figure 2), les différences de vigueur sont davantage liées aux caractéristiques de la parcelle et au porte-greffe qu’à la hauteur de greffage. Toutefois, il faut préciser que pour certaines combinaisons porte-greffe/variété, les greffages hauts entraînent une perte de vigueur par rapport au greffage à 20 cm (16% en moyenne). L’augmentation de la densité de plantation permet de compenser à l’hectare cette diminution.
Figure 2. Incidence du greffage haut sur la vigueur (section du tronc en cm²), année 2005.

Production:
Au niveau de la production (kg/arbre), on constate également que les différences sont plutôt dues au porte-greffe qu’à la hauteur de greffage (figures 3 et 4, tableau 1). Pour le cas de Rubira (pour les deux sites et variétés testées), les greffages hauts n’influencent pas négativement la production des arbres. Pour P2315 et Manicot (porte-greffe vigoureux), les résultats sont partagés : dans le premier cas il y a une perte de 20 % avec les greffages à 120 cm (Drôme), tandis que dans le deuxième cas le greffage haut présente un meilleur comportement (Gard). Toutefois, on constate que la productivité (variable qui met en relation la production et la vigueur) est faiblement affectée par la hauteur de greffage.

Figure 3 et 4. Incidence du greffage haut sur la production cumulée (kg/arbre) et le poids moyen des fruits (grammes).

Tableau 1. Productivité (kg/cm²)

<table>
<thead>
<tr>
<th>Porte-greffe (cov)</th>
<th>Orangered® Bhart</th>
<th>Early Blush® Ruthhart</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P2315</td>
<td>Rubira</td>
</tr>
<tr>
<td></td>
<td>Manicot</td>
<td>Rubira</td>
</tr>
<tr>
<td>hauteur</td>
<td>0.2m 0.6m 1.2m</td>
<td>0.2m 0.6m 1.2m</td>
</tr>
<tr>
<td></td>
<td>0.2m 0.6m 1.2m</td>
<td>0.2m 0.6m 1.2m</td>
</tr>
<tr>
<td>Productivité Kg/cm²</td>
<td>0.93 0.83 0.87</td>
<td>1.04 0.98 1.2</td>
</tr>
<tr>
<td></td>
<td>0.46 0.52 0.43</td>
<td>0.46 0.52 0.48</td>
</tr>
</tbody>
</table>
**Temps de travaux:**
Afin d'évaluer l’influence du greffage haut sur les temps de travaux, nous avons comparé la moyenne des heures par hectare et par an entre les modalités (figures 5 et 6).

Tout d’abord, on observe que le chantier récolte est celui qui demande le plus de main d’œuvre. Par conséquent, les modalités qui présentent les valeurs de production (kg de fruits/arbre) les plus importantes sont aussi celles pour lesquelles les temps de travaux sont les plus élevés. Cependant, on peut imaginer que la relation entre les deux variables n’est pas linéaire pour certaines modalités. Ainsi, nous avons étudié l’efficacité du chantier ramassage, en calculant le rapport heures/tonne/ha. Comme on peut observer sur le tableau 2, les heures/tonne des greffages hauts (120 cm) sont soit du même ordre, soit inférieures à celles des greffages à 20 cm. On retrouve en revanche, pour le porte-greffe P2315 que les greffages intermédiaires sont un peu moins performants. Par ailleurs, on constate aussi que les faibles différences au niveau de la vigueur entre les hauteurs de greffages ne provoquent pas une différence sur les temps de taille.

Ces résultats nous permettent d’affirmer que le greffage haut n’induit pas par lui-même une surchargé de temps de travail.

Figure 5 et 6. Incidence du greffage haut sur les temps de travaux.

**Tableau 2. Efficacité du chantier récolte sur la variété Orangered® Bhart (cov).**

<table>
<thead>
<tr>
<th></th>
<th>P2315</th>
<th>Rubira</th>
</tr>
</thead>
<tbody>
<tr>
<td>hauteur</td>
<td>0.2m</td>
<td>0.6m</td>
</tr>
<tr>
<td></td>
<td>0.2m</td>
<td>0.6m</td>
</tr>
<tr>
<td>heures/tonne/ha</td>
<td>17.6</td>
<td>20.3</td>
</tr>
<tr>
<td></td>
<td>20.5</td>
<td>17.8</td>
</tr>
</tbody>
</table>

Dans les conditions de nos essais, l’utilisation du greffage haut ne montre pas d’inconvénients agronomiques ou économiques majeurs, alors qu’au niveau sanitaire ses avantages sont irréfutables. Une augmentation de la densité de plantation liée à une possible diminution de la vigueur peut être envisagée afin d’améliorer les rendements/ha.

**Comportement agronomique du porte-greffe Rubira**
Afin de mieux adapter le développement du porte-greffe Rubira, un approfondissement sur ses performances agronomiques été nécessaire. Pour cela nous avons comparé entre un porte-greffe de référence (GF 305) et Rubira, la vigueur et la capacité productive d’une gamme variétale. Les résultats agronomiques de certaines variétés étudiées sont présentés sur les figures 7 et 8.
On constate ainsi que Rubira induit une perte de vigueur variable selon la variété. Dans les conditions de l’essai, certaines variétés montrent un léger affaiblissement (de 0 à 20 %), jusqu’à de fortes pertes de vigueur (moins 40 %). L’utilisation du porte-greffe Rubira requiert alors une adaptation de la densité de plantation afin d’améliorer le rendement par hectare.

En ce qui concerne la production, Rubira induit les mêmes différences que celles observées pour la vigueur. Les pertes de production sont ainsi variables selon la variété, pouvant aller jusqu’à 30 %. En revanche, Rubira montre un niveau de productivité (tableau 3) très similaire à celui du porte-greffe témoin (au calibre similaire), ce qui nous permet de le conseiller sur la plupart des variétés tout en adaptant sa densité de plantation.

Il faut préciser que les valeurs de pertes de production et de vigueur constatées sont des valeurs estimatives, relatives à l’essai et donnent simplement un ordre d’idée du comportement du porte-greffe.

![Diagram](image.png)

Figure 7 et 8. Section du tronc (cm²), arbres de 8 ans et production cumulée et poids moyen des fruits 2000-05/Drôme

**Tableau 3. Productivité (kg/cm²)**

<table>
<thead>
<tr>
<th></th>
<th>Early blush® Rubhart (cov)</th>
<th>Tom Cot® Toyaco (cov)</th>
<th>Robada (cov)</th>
<th>Harostar (cov)</th>
<th>Hargrand</th>
<th>Bergarouge® Avirine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rubira</td>
<td>0.50</td>
<td>1.09</td>
<td>1.27</td>
<td>0.78</td>
<td>1.0</td>
<td>0.56</td>
</tr>
<tr>
<td>GF305</td>
<td>0.38</td>
<td>1.13</td>
<td>0.95</td>
<td>0.75</td>
<td>1.10</td>
<td>0.69</td>
</tr>
</tbody>
</table>

Les résultats d’essais présentés ci-dessus nous ont permis de mieux connaître le comportement agronomique et sanitaire du porte-greffe Rubira ainsi que les effets bénéfiques des greffages hauts, nous permettant ainsi de les inclure comme deux nouvelles mesures prophylactiques de lutte contre la bactériose de l’abricotier.

**Bibliographie**

Summer damage on nectarine by thrips: seasonal abundance and control methods

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Abstract: To define the origin of colour alterations on early ripening nectarine fruits, field and laboratory investigations have been conducted in the peach growing area of Piedmont (North West Italy), in the 2002-2005 period. Such alterations (losses of the skin colour in fruit-fruit and leaf-fruit contact zones) were caused by thrips feeding in the period from the veraison to the commercial ripening of fruits. During surveys, the most abundant species was *Thrips fuscipennis* Haliday (Thysanoptera Thripidae), whose populations reached maximum levels on plants between late June and early July. Visual inspection and beating of apical leaves revealed to be a reliable sampling method to monitor thrips population dynamics, but to forecast fruit damage the unique trustworthy method was the direct counting of thrips per fruit. Among the active ingredients tested in laboratory and field trials, spinosad was the most effective to control thrips, also at lower doses than label recommendations and with mineral oil. Thus, defence strategies should include two applications to cover the 20 days from veraison to harvest; the first application could be useful to control also other insect pests while the second one should be considered specific against thrips.

Key words: Peach, *Thrips fuscipennis*, sampling methods, population dynamics, spinosad.

Introduction

With 22,000 hectares of intensive orchards, the Piedmont region is among the most important fruit growing areas in Italy (ISTAT 2004). The peach/nectarine group represents 36% of the regional production, despite the recent decrease of the growing area due to a lower sale. Nectarine varieties represent 50% of peach orchards especially after the introduction of early ripening cultivars starting from 1990. Most of these varieties are characterized by an intense and uniform colour, an essential requirement for new markets.

In the last years, losses of skin colour in fruit-fruit and leaf-fruit contact zones began to appear, at first sporadically and then throughout the fruit growing area. Similar symptoms have been already reported in other fruit growing areas and ascribed to the feeding activity of thrips (Ciampolini *et al.*, 1995, Grasselly & Lacasa, 1995, Felland *et al.*, 1995, Ceredi & Tommasini, 2004). Since such damage has become economically important in Piedmont, a 4-year research was carried out to identify the pest responsible for this damage, to assess its population distribution and dynamics, and to develop efficacious defence strategies.
Materials and methods

Distribution and population dynamics of the pest responsible for damage
Field and laboratory activities were conducted during 4 years, 2002-2005. In the first 2 years, insect populations were periodically sampled in six Big Top cultivar orchards that presented the highest amounts of damage in the fruit growing area during previous years. To monitor insect populations and define reliable and feasible sampling methods, from April to harvest thrips were weekly collected and counted on 25 plants per orchard by visual inspection of 50 apical leaves and beating of 50 buds on a rigid sheet (250×350 mm). Moreover, from May to harvest thrips were fortnightly counted on 50 fruits from 25 plants per orchard. In the laboratory, field-sampled thrips were then divided by stage, counted again, and stored in ethanol 70%. Adults were determined using the dichotomic key by Mound et al. (1976).

Evaluation of different active ingredients and defence strategies
To evaluate the effectiveness of different active ingredients (a.i.) and defence strategies against thrips, field control trials were carried out during 3 years, 2002-2004. In 2002, spinosad (Laser 44.2%, 20ml/hl, 21 days to harvest), lufenuron (Match 5.32%, 200ml/hl, 21 days to harvest), and Beauveria bassiana (Balsamo) Vuillemin+pinolene (Naturalis 7.16%, 150ml/hl and Vapor Gard 96%, 30ml/hl, 21, 17 and 11 days to harvest) were tested. In 2003 spinosad (Laser 44.2%, 20ml/hl) applied once (20 days to harvest) and twice (20 and 7 days to harvest) was compared with fenitrothion (IPM 400 36%, 300ml/hl, 20 days to harvest) and malathion (Smart EW 40%, 150ml/hl, 20 days to harvest). In 2004 other three a.i. were applied 14 and 7 days before harvest: abamectin (Vertimec EC, 18g/l, 150ml/hl), acrinathrin (Rufast EW, 75g/l, 80ml/hl) and lambda-cyhalothrin (Karate Zeon CS, 100g/l, 27ml/hl). Moreover, the following control strategies were tested:

A) fenitrothion (Fenitrocap 23.15%, 350 ml/hl) 20 days to harvest and spinosad (Laser 44.2%, 25 ml/hl) 12 days to harvest;
B) fenitrothion (Fenitrocap 23.15%, 350 ml/hl) 20 days to harvest and spinosad (Laser 44.2%, 15 ml/hl) + mineral oil (Biolid 80%, 500 ml/hl) 12 days to harvest;
C) malathion (Smart EW 40%, 150 ml/hl) 20 days to harvest and acrinathrin (Rufast E-Flo 7.01%, 70 ml/hl) 12 days to harvest;
D) spinosad (Laser 44.2%, 15 ml/hl) and mineral oil (Biolid 80%, 500 ml/hl) 20 and 12 days to harvest.

Field trials were organized as a randomized block design, with 4 replications per thesis, and 4-5 plants per replication. Spray interventions, following the commercial agrochemical label indications, were made using a shoulder atomizer with a water volume of 11-12hl/h. At harvest, damage was evaluated as percentages of fruits damaged on 250 fruits/replication. Data were then analyzed by means of Tukey test (P<0.05).

In 2004, side effects of the tested a.i. on the phytoseiid mite Amblyseius andersoni Chant, the main predator of tetranychid mite Panonychus ulmi Koch, were also evaluated by sampling 100 leaves per thesis (25 per replication) and assessing percentage of infested leaves and mean number of larvae and adults per leaf.

Results and discussion

Distribution and population dynamics of the pest responsible for damage
As in other Italian peach growing areas, also in Piedmont damage to nectarines was caused by the feeding activity of thrips. However, whereas in other Italian regions the pests responsible for damage were Frankliniella occidentalis (Pergande), Thrips major Uzel, and T. tabaci Lindeman, in our region the most abundant species sampled on peach was Thrips fuscipennis
This thrips, highly polyphagous (Marullo, 2003), has already been reported in Piedmont in both open field and greenhouse crops, such as bean, blackberry, raspberry, strawberry and grapevine (Gremo et al., 1997).

T. fuscipennis was present in all investigated peach orchards, regardless of the peach variety group; however, damage was significant only on early ripening nectarines, especially on Big Top group. In the 4-year surveys, the population levels showed a variability based on year and orchard, on the average higher in 2002 and 2005, and lower in 2003 and 2004. By contrast, seasonal abundance was nearly similar: populations of T. fuscipennis reached a maximum density in plants between late June and early July. Thrips were at first observed on peach leaves from late May, then on fruits from mid-June, at the beginning of the veraison, until fruit harvest. Therefore, the period of damage risk was around 20 days before the first fruit harvest.

Concerning sampling methods, data on thrips infestations obtained by means of visual inspection of apical leaves and beating of buds were strictly correlated; however, to forecast fruit damage the only trustworthy method was the direct counting of thrips per fruit, differently from what was observed by Tommasini and Burgio (2004).

**Evaluation of different active ingredients and defence strategies**

So far, a few a.i. have been tested for efficacy in reducing fruit damage caused by summer thrips attacks and side effects such as their influence on phytoseiid mite predators of P. ulmi. Results of the 3-year field control trials are hereafter summarized; the efficacy percentages are expressed as damage reduction, corrected for control according to Abbott’s formula.

- Lufenuron and B. bassiana were ineffective to control thrips, B. bassiana even with repeated spray interventions every 6-7 days and addition of pinolene to increase the stability of a.i. on plants.
- Malathion and fenitrothion showed an efficacy degree from 30 to 50%. These a.i., usually included in IPM strategies to control Lepidoptera Tortonica, can be effective with low thrips infestation levels or when used to control at the same time thrips, Grapholita molesta (Busck) and/or Anarsia lineatella (Zeller), 20 days before harvest;
- Acrinathrin and lambda-cyhalothrin displayed a good efficacy of about 80% but they are not included in current fruit IPM guidelines due to their side effects on beneficial organisms;
- Abamectin, alone or blended with mineral oil, reached on average an efficacy of 80% without any side effects;
- Spinosad was the most effective (90-95%) even at a low dose (15 instead of 25 ml/hl) blended with mineral oil; no side effects were observed during trials.
The increase of damage between the first and the second harvest revealed that a unique treatment was generally insufficient to control thrips. By contrast, all control strategies tested in 2004 proved to be effective to reduce fruit damage with values lower than 1% and significantly different from 7% observed in untreated control (Tukey test, P<0.05), even though it must be said that thrips population pressure was low throughout the growing season. Spinosad confirmed its efficacy even at lower doses than label recommendations and with mineral oil. The use of malathion and acrinathrin caused side effects, i.e. outbreaks of *P. ulmi* (data not shown).

In conclusion, based on the population dynamics described above, in particular on data of years characterized by high populations, defence strategies should include two spray interventions against thrips: the first about 20 days before harvest, the second after 8-10 days depending on the used a.i. Moreover, the application of spinosad at a lower dose blended with mineral oil seems interesting in order to reduce defence costs.

**Acknowledgements**

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**References**

Management of oriental fruit moth with ground ULV spray applications of a microencapsulated sex pheromone

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USDA, ARS, Wapato, WA. USDA, ARS, Albany, CA. UC Cooperative Extension, Yuba City, CA. Uludag University, Bursa, Turkey. Istituto di Entomologia e Patologia vegetale, Piacenza, Italy.

Abstract Sex pheromones have been widely used to manage oriental fruit moth (OFM) in stone fruits for 30 years. Microencapsulated formulations of sex pheromone have been developed and have proven to be an effective tactic. Recently, we developed the use of ultra low volume (ULV) ground applications of these microencapsulated products. The ULV spray is less expensive to apply and provides growers greater flexibility in adjusting their management programs for OFM. Studies in California and Turkey have demonstrated that ULV sprays can be effective. The advantages and problems associated with this new tactic and its potential adoption by growers are discussed.

Key words: oriental fruit moth, stone fruits, mating disruption, ultra low volume

Introduction

Oriental fruit moth, *Cydia molesta* (Busck), (OFM) is a key worldwide pest of stone fruit (Rothschild *et al*., 1991). Development of various hand-applied sex pheromone dispensers has provided a very effective strategy to manage its population (Cardé & Minks, 1995). However, one drawback for growers in adopting the use of hand-applied dispensers, which are applied at the start of the growing season, is the variability in the harvest dates of adjoining blocks of stone fruit. In many cases, growers do not manage OFM after harvest and populations in early-season cultivars can build-up and attack late-season cultivars. Many types of hand-applied dispensers do not last the entire year and growers must supplement their use with either a second dispenser application and/or the use of insecticides (Rice & Kirsch, 1990).

Among alternative to the use of hand-applied dispensers for MD are spray applications of microencapsulated sex pheromone formulations (Trimble *et al*., 2004; Kovanci *et al*., 2005). Microencapsulated sprayables are widely used in stone fruit in the east coast of the United States where they are applied to alternate rows in combination with fungicides (Hull & Ellis, 2002). The ease of applying microcapsules with conventional equipment is a major factor generating growers’ interest in sprayables. Sprayable sex pheromone formulations increase a grower’s flexibility in adjusting application rates and timings during the season. In addition, microcapsules can be tank-mixed with other pesticides and can easily be included within a grower’s integrated control program. The OFM sprayables have been effective in several season-long field trials; however, questions of their efficacy early in the season when deposition of capsules is problematic and late in the season due to reduced longevity during warm weather exist. Concerns about spraying sex pheromones late in the season with conventional tractor-pulled sprayers include the risk of blowing fruit off of the trees and delays in treating orchards following irrigation cycles have limited the use of sprayables for OFM (Pickel *et al*., 2002).
A potential improvement in the use of microencapsulated sex pheromones was developed in 2001 using ultra low volume (ULV) spray applications (12.0 l per hectare) from a small, all-terrain vehicle (ATV) for codling moth, *Cydia pomonella* (L.). The use of a more concentrated spray applied at low air pressure (< 30 psi) from two nozzles was found to significantly increase the deposition of capsules on the foliage (7X higher) and this approach significantly improved the performance of this technology (Knight and Larsen 2004). Similar studies were conducted with a microencapsulated formulation for OFM and the ULV approach deposited 4X more capsules than the standard air blast application. This suggests that growers may be able to significantly reduce their costs by lowering the rate of material applied. The use of the ATV also minimizes problems in treating orchards following an irrigation cycle and would not blow fruit off of trees. The ULV approach could be used as a stand-alone program or late in the season to supplement hand-applied dispensers in late-season cultivars. Studies were initiated in 2005 and preliminary results from the United States and Turkey are reported here.

**Material and methods**

**California 2005**

A study was initiated near Yuba City, CA on 2 March to evaluate the ULV applications of *Checkmate® OFM-F* (Suterra LLC, Bend, OR). Four replicated plots (0.25 ha) each with three treatment rates of the ULV spray (5.0, 12.4, and 24.7 g a.i. per hectare), a hand-applied dispenser treatment (300 Checkmate OFM-XL dispensers per hectare), and an untreated control were randomly placed in a mixed cultivar peach orchard. Plots were separated by >50 m. *Checkmate® OFM-F* is a blend of 21.86% (Z)-8-dodecenyl acetate (Z8-12:Ac), 1.47% (E)-8-dodecenyl acetate (E8-12:Ac), and 0.27% (Z)-8-dodecen-1-ol (Z8-12:OH), and is typically applied as a full-coverage spray at 20 – 40 g a.i. per hectare. Dispensers contained 250 mg a.i. (11.93% Z8-12:Ac, 0.80% E8-12:Ac, and 0.15% Z8-12:OH). Dispensers and the first ULV spray were applied on 3 March. The ULV spray was applied in 12.0 l of water per hectare. The second application on 14 April was made under high winds (65 km/h gusts), and deposition of microcapsules under these windy conditions was likely poor. The pump was found to be faulty during the third application made on 3 June due to corrosion by the sex pheromone and plots may have received a highly variable pheromone treatment. Further equipment problems were avoided by rinsing all equipment with an alcohol mixture after each application. Subsequent ULV sprays were applied on 5 July and 30 July. Plots were monitored weekly with two pairs of sex pheromone-baited delta traps. Lures were changed every 4 weeks. Fruit injury assessments were made for the mid-season and late-season varieties within plots on 1 and 18 August, respectively. On each date 720 fruits per plot were examined. The entire orchard was sprayed with two applications of esfenvalerate (Asana XL, Dupont Crop Protection, Newark, DE) during the season at 600 ml per 1000 l water per hectare.

**California 2006**

The study was repeated in the same orchard situated near Yuba City, CA. Five replicates of each treatment (dispenser, ULV spray, and untreated) were randomly established and plots were separated by > 50 m. The Checkmate hand-applied dispenser was put out on 15 March. A 50% rate of the microencapsulated formulation (12.4 g AI per hectare) was used and the first spray was not applied until the beginning of the second moth flight (1 May). Subsequent applications were made on 2 June, 28 June, and 3 August. The mid-season cultivar was sampled on 3 August and the late-season cultivar on 21 August. One hundred fruits per plot were examined for injury on each date. The entire orchard was sprayed with one application of esfenvalerate during the season at 1,170 ml per 1,000 l water per hectare.
Turkey 2006
Larger plot studies were conducted to compare the efficacy of OFM mating disruption treatments with conventional insecticide control. Each treatment was replicated at two study sites near Bursa, northwestern Turkey. Study sites were composed of ‘Redhaven’ and ‘Cresthaven’ peaches. For all treatments, Thiacloprid (Calypso 480 SC, Bayer, Turkey) was applied at a rate of 375 ml in 1000 l water for control of the first OFM generation. Mating disruption treatments were initiated in June, just before emergence of second-generation adults. At each orchard four 4 ha plots separated by 100 m were established and one of four treatments were randomly assigned to each plot. A nonpheromone-treated conventional block was sprayed with four applications of insecticides during the season including Novaluron, Thiacloprid, Diazinon, and Methidathion. Checkmate® OFM-SF hand-applied dispensers loaded with 180 mg of OFM synthetic sex pheromone (8.6% Z8-12:Ac, 0.52% E8-12:Ac, and 0.09% Z8-12:OH) and 200 mg of peach twig borer pheromone (8.34% (E)-5-Decenyl acetate, 1.73% and (E)-5-Decen-1-ol) were applied at 350 dispensers per hectare. The Checkmate® OFM-F (15.0 g a.i.) was applied at monthly intervals on 2 June, 30 June, and 27 July in either ULV sprays of 24 l water/ha or in high volume (HV) sprays of 768 l/ha. A standard air blast sprayer was used for both treatments. With the ULV application the number of operating nozzles was reduced from eight to two, the speed of tractor was increased from 2 to 6 km/h, and the nozzle pressure was reduced from 60 to 15 PSI. Four pheromone traps were placed in each plot and lures and traps were replaced every 2 months. Fruit injury was assessed at harvest. Fruit damage was evaluated by picking 100 fruit arbitrarily from each of 10 trees per treatment.

Data from all studies were transformed prior to analysis of variance using SQRT (x+1) for count data and ARCSIN(SQRT(x)) for the proportion of injured fruits. Fisher’s LSD test was used to detect treatment differences in significant ANOVA’s, at $P < 0.05$.

Results

California 2005
Significant reductions in mean moth catches per trap occurred in pheromone treatments versus plots without pheromone throughout the season except early in the season (Table 1). Rainfall occurred consistently following the first sex pheromone application in March and continued frequently through April. Thus, moth catches were not well disrupted in the ULV plots during this time period. Largely due to the mechanical problems encountered during the third ULV application, moth counts were high though variable during the second time period (Table 1). However, following the 4th and 5th ULV sprays moth counts remained low during the rest of the season in these plots.

Significant differences in levels of OFM fruit injury occurred among treatments (Table 1). Fruit injury was higher in the untreated than in all sex pheromone treatments. Fruit injury was significantly lower in the 5.0 g and 12.4 g ULV treatments than the in plots treated with dispensers. Mean fruit injury in ULV-treated plots with the highest pheromone rate was not significantly different from either the dispenser or the two lower ULV rate treatments.

California 2006
Moth catches were much lower in the Yuba City orchard in 2006 versus 2005 (Table 2). Following the first ULV application (delayed until May) no significant difference in moth catches occurred between either pheromone treatment and both were significantly lower than in the untreated plots. Levels of fruit injury were very low in all plots and no difference was found among treatments.
Table 1. Comparison of mean cumulative moth catches in sex pheromone-baited traps and fruit injury by OFM in replicated plots (n = 4) treated with either hand-applied dispensers, three rates of a microencapsulated sex pheromone applied as an ultra low volume spray or in untreated plots in a Yuba City, CA peach orchard in 2005.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean (SEM) cumulative moth catch per trap between</th>
<th>% fruit injury b</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st and 2nd spray</td>
<td>3rd and 4th spray</td>
</tr>
<tr>
<td>No pheromone Dispensers</td>
<td>23.4 (9.2)a</td>
<td>182.5 (34.3)a</td>
</tr>
<tr>
<td>300/hectare</td>
<td>0.0 (0.0)c</td>
<td>0.1 (0.1)b</td>
</tr>
<tr>
<td>ULV spray 5.0 g a.i.</td>
<td>14.5 (2.9)ab</td>
<td>48.4 (20.4)b</td>
</tr>
<tr>
<td>ULV spray 12.4 g a.i.</td>
<td>7.3 (1.8)bc</td>
<td>17.6 (6.9)b</td>
</tr>
<tr>
<td>ULV spray 24.7 g a.i.</td>
<td>6.9 (1.5)bc</td>
<td>18.0 (7.5)b</td>
</tr>
<tr>
<td>ANOVA:</td>
<td>$F_{4,15} = 3.96$</td>
<td>$F_{4,15} = 16.30$</td>
</tr>
<tr>
<td></td>
<td>$P = 0.013$</td>
<td>$P &lt; 0.0001$</td>
</tr>
</tbody>
</table>

Means in the same column followed by the same letters were not significantly different, LSD test, $P < 0.05$.  

a All ULV sprays were applied in 12 l of water per hectare. Sprays were applied on 3 March, 14 April, 3 June and 30 July.  
b Fruit were sampled on 1 and 18 August, 720 per plot.

Table 2. Comparison of mean cumulative moth catches in sex pheromone-baited traps and fruit injury by OFM in replicated plots (n = 5) treated with either hand-applied dispensers, a microencapsulated sex pheromone applied as an ultra low volume spray or in untreated plots in a Yuba City, CA peach orchard in 2006.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean (SEM) cumulative moth catch per trap between</th>
<th>% fruit injury b</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dispensers applied and 1st spray</td>
<td>2nd and 3rd spray</td>
</tr>
<tr>
<td>No pheromone Dispensers</td>
<td>12.1 (3.8)a</td>
<td>5.6 (1.3)a</td>
</tr>
<tr>
<td>300/hectare</td>
<td>0.2 (0.2)b</td>
<td>0.0 (0.0)b</td>
</tr>
<tr>
<td>ULV spray 12.4 g a.i.</td>
<td>6.5 (1.9)ab</td>
<td>0.2 (0.2)b</td>
</tr>
<tr>
<td>ANOVA:</td>
<td>$F_{2,12} = 5.90$</td>
<td>$F_{2,12} = 17.10$</td>
</tr>
<tr>
<td></td>
<td>$P = 0.02$</td>
<td>$P = 0.0003$</td>
</tr>
</tbody>
</table>

Means in the same column followed by the same letters were not significantly different, LSD test, $P < 0.05$.  

a Dispensers were applied on 15 March. All ULV sprays were applied in 12 l of water per hectare. Sprays were applied on 1 May, 2 June, 28 June, and 3 August.  
b Fruit were sampled on 3 and 21 August, 100 per plot.
Turkey 2006
Both sex pheromone dispensers and the ULV and HV spray applications of sex pheromone significantly reduced moth catches compared with the untreated plots until late in the season (Table 3). The mean level of fruit injury was not significantly different among treatments.

Table 3. Comparison of mean cumulative moth catches in sex pheromone-baited traps and fruit injury by OFM in plots treated with either hand-applied dispensers, a microencapsulated sex pheromone applied either as an ultra low volume or a high volume spray or in insecticide-only treated plots in two peach orchards near Bursa, Turkey in 2006.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean (SEM) cumulative moth catch per trap between</th>
<th>% fruit injury b</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st and 2nd spray</td>
<td>2nd</td>
</tr>
<tr>
<td></td>
<td>2nd and 3rd</td>
<td>3rd spray</td>
</tr>
<tr>
<td>Insecticides</td>
<td>8.0 (2.8)a</td>
<td>29.5 (14.8)a</td>
</tr>
<tr>
<td>Dispensers 350/hectare</td>
<td>0.0 (0.0)b</td>
<td>0.5 (0.3)b</td>
</tr>
<tr>
<td>ULV spray 15.0 g a.i.</td>
<td>0.8 (0.3)b</td>
<td>2.3 (1.8)b</td>
</tr>
<tr>
<td>HV spray 15.0 g a.i.</td>
<td>0.8 (0.0)b</td>
<td>3.3 (0.3)b</td>
</tr>
</tbody>
</table>

ANOVA: $F_{3,4} = 14.10$ $F_{3,4} = 6.45$ $F_{3,4} = 1.39$ $F_{3,4} = 5.38$

$P = 0.01$ $P = 0.05$ $P = 0.37$ $P = 0.07$

Means in the same column followed by the same letters were not significantly different, LSD test, $P < 0.05$.

Checkmate® OFM-SF dispensers were applied on 2 June. ULV sprays were applied in 24 l water per hectare and HV sprays were applied in 768 l per hectare.

Fruit were sampled on 2 August, 1,000 per plot.

Discussion
The season-long ULV spray application of sex pheromone was found to be a very effective program for management of OFM in stone fruit orchards in California during 2005. Yet, it was clear that the early-season ULV applications were compromised by the wet spring weather that occurs frequently in California. Modifying this five-spray application program by starting sprays later in the season appears to be a reasonable approach. Unfortunately, the populations of OFM were very low in California during 2006 and the data did not allow for comparison of the effectiveness of hand-applied dispensers with the ULV sprays. Yet, the data does strongly suggest that using a ½ rate of the microencapsulated sex pheromone was effective in suppressing moth catches in traps throughout the season. Cutting the cost of material by 50% would be a significant factor promoting the use of the sprayable formulation. Growers in California continue to disagree whether the 1st generation of OFM in the spring needs to be actively managed. Yet, it is more likely that populations of OFM early in the season will be problematic following the grower’s failure to maintain mating disruption the previous season following harvest. This ‘rebound’ effect after harvest may be an important factor maintaining OFM as a serious pest year-after-year in some orchards. In addition, the record levels of spring
precipitation during the past two seasons in California have made early-season management of OFM difficult. Thus, it seems reasonable to consider the adoption of maintaining mating disruption of OFM populations after harvest in early and mid-season cultivars by applying reduced rates of microencapsulated sprayables. Additional studies are needed to assess the potential value of this multi-season management program for OFM.

Our results with the ULV spray from Turkey do not appear to be consistent with the results from California. However, significant differences existed between these experimental programs that could explain these differences. During 2006 only three pheromone sprays were applied in Turkey and the program did not start until June versus May in California. Secondly, the similarity between the modified air blast sprayer and the ATV-mounted sprayer has not been determined. The key to assessing any specific approach using microencapsulated pheromone formulation is to quantify both the density and distribution of microcapsules deposited on the crop (Waldstein and Gut 2003). Similar to knowing the emission characteristics of a hand-applied dispenser, it is essential to quantify the effectiveness of each spray application in depositing microcapsules and the microcapsules’ effective residual period. Other factors such as irrigation, precipitation, weather extremes, could also create significant differences in the effectiveness of the microencapsulated formulation between regions or orchards and these factors will need to be assessed in future collaborative projects.

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References


Effect of winter pruning on the peach-Myzus persicae interaction

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Abstract: Application of modeling to horticulture is not new and many models have been developed for fruit production and pest management. However, few models investigate at the same time (i) the responses of fruit tree to pest attacks and their effects on fruit quality, (ii) the regulation of pest population in relation to tree status and (iii) the response of whole system to technical operations. Improvement of Integrated Fruit Production practices require to approach all these issues in an integrated way. A modeling approach integrating peach – green peach aphid (Myzus persicae) system with technical operations (nitrogen fertilisation, winter pruning and biological control) is therefore under investigation in Avignon INRA research centre. An experiment was conducted to study how the intensity of winter pruning affects peach tree and aphid population and how the aphid population level affects peach production. The treatments included infested and non-infested trees and a pruning intensity gradient. Results showed that average shoot growth and degree of aphid infestation of peach tree increased with increasing pruning intensity. Aphids induced shoot-tip damage, leaf curling and leaf fall. However, aphids poorly reduce fruit quality.

Key words: green peach aphid, Myzus persicae, peach, cultivar practices, winter pruning, Integrated Fruit Production, model

Introduction

In most European countries, the concept of Integrated Fruit Production (IFP) has been adopted since the late 1980s (Sansavini, 1997) and it is now an important field of research at the Avignon INRA centre. IFP is an integrated approach to fruit production that gives priority to natural, cultural and biological methods in the control of fruit tree pests (Müller, 2000). However to develop such an approach, a better understanding of the interactions between components of the crop-pest system and their relationships to the environment and management practices is required (Getz & Gutierrez, 1982). The study of these interactions in specific agro ecosystems, e.g. orchards of southeastern France, is currently under investigation in Avignon. In particular, a study on Myzus persicae (Sulzer) control in peach orchard is carried out.

M. persicae is one of the most serious pests of peach (Prunus persica L. Batsch) in Europe. For many years, chemicals have been used to control aphids in orchards. The impact of pesticides on the environment and the increasing development of resistance to pesticides in aphid populations (Mazzoni et al., 1999; Ansted et al., 2005) call for other aphid management alternatives than the simple reliance on pesticide use. Vigorous plants are supposed to be favorable to aphid development (Brown & Welker, 1992; Price, 1991). On the other hand, it is well known that plant nitrogen status influences aphid performances (van Emden, 1966). Consequently, winter pruning, which influences plant growth and vigour, and nitrogen
fertilization may be investigated as potential complementary control methods. The present study is conducted to understand and model the interactions between aphids, peach tree and aphid natural enemies (e.g. *Harmonia axyridis*) under the influence of winter pruning and nitrogen fertilization. In its simple form (Fig. 1), the system is composed of an homogeneous tree (including roots, shoots and fruits), an homogeneous aphid population and cohorts of ladybird larvae (*Harmonia axyridis* Pallas). The model will be used to investigate the dynamic behaviour of the whole system, including fruit quality, in response to different orchard management strategies and to identify those most adapted to IFP.

As part of this study, an experiment was conducted to evaluate the effects of winter pruning on tree vegetative growth and *M. persicae* population dynamics and the effects of aphids on tree vegetative growth, yield and fruit quality. Results obtained from the experiments of 2005 and 2006 are presented.

**Material and methods**

**Orchard management and experimental treatments**

Data were collected in 2005 and 2006, from an experimental peach orchard (cultivar ‘Suncrest’) of INRA institute in Avignon (southeast of France). It comprised 20 trees (10 per row) placed under an insect proof shelter in order to isolate trees from the environment. Apart from winter pruning and insecticide applications, all trees were managed according to normal commercial practices, e.g. fertilization, irrigation and fruit thinning (28-30 cm 1-year-old wood per fruit).

The orchard was separated into 12 infested trees (I) and 8 non-infested trees (non-I). Insecticides were used only on trees of non-infested treatment. In 2005, aphids emerged from winter eggs. In autumn 2005, the insect proof shelter prevented aphids from flying back to the trees and laying eggs. So, trees of the 'I' treatment were manually infested in April and May 2006 with aphid colonies reared in the laboratory. A total of 176 aphids were deposited on 24 shoots per tree.

Pruning treatments, made of a scale intensity from 0 to 80%, were assigned randomly to both infested and non-infested trees. Pruning intensity (IP) was defined as the percentage of...
mass ratio of 1-year-old-wood pruned on total 1-year-old-wood. The mass of the non-pruned 1-year-old-wood was assessed by measuring it length and using an allometric relationship.

**Sampling and monitoring**
At bud burst, 60 shoot buds per tree were tagged. They were selected systematically to be distributed all over the crown of the tree.

Vegetative growth was monitored on 36 of the tagged shoots by measuring the number of leaves per shoot every 15 days from mid-April to August and total shoot length on one main scaffold at the end of the growing season. The number of curled leaves and damaged shoot tips were also recorded.

36 fruits per tree were sampled and used to monitor fruit growth by measuring cheek diameter every 15 days from mid-May to harvest. The same fruits were used to evaluate fruit quality at harvest, e.g. fruit size, fresh weight, flesh water content and refractometric index.

Monitoring the population of aphids was carried out every week, from mid-April until the period when no aphid was observed on trees. All the tagged shoots were described using a classification adapted to colony-level infestati on degrees and an index of relative infestation (IF) was calculated for each tree following the formula of Chen (1997):

\[
IF = \frac{\sum (d \cdot f_d)}{5 \cdot \sum f_d}, \quad d=0.5
\]

where \(d\) is the degree of infestation (\(d \in [0,1,2,3,4,5]\)) and \(f_d\) is the frequency of \(d\)

- **degree 0**: number of aphids \(N = 0\)
- **degree 1**: slightly infested, \(5^0 < N \leq 5^1\)
- **degree 2**: obviously infested, \(5^1 < N \leq 5^2\)
- **degree 3**: top 2-3 leaves become curled, \(5^2 < N \leq 5^3\)
- **degree 4**: 3-5 leaves curled, aphids crowd the top of shoot, \(5^3 < N \leq 5^4\)
- **degree 5**: aphids crowd all over the top of the shoot and more than 5 leaves, \(5^4 < N\)

**Results and discussion**

**Tree vegetative growth**
Pruning intensity influenced the time-course of shoot growth, expressed as the number of leaves per shoot. The average shoots of high IP group maintained their growth throughout the season whereas those of low IP group stopped their active growth early in the season. In the case of medium IP group, active shoot growth was maintained only in 2006 but at a lower rate compared with high IP group (Fig. 2A). Consequently, at the end of the season, the number of leaves of an average shoot increased significantly with increasing pruning intensity (Fig. 2B). For non-infested trees, it can be predicted by the following model: \(y = a + \exp(b \cdot x^2)\), with \(a=4.96\) (SE=0.31), \(p<0.1\%\) and \(b=4.20e-04\) (SE=0.14e-04), \(p<0.1\%\).

The relationship above was mainly caused by a modification of the structure of shoots on the tree. Shoots can be classified into 2 groups, with different growth patterns: shoots without stem elongation (rosettes, R), and shoots with stem elongation (growing shoots, GS). The first had their growth only in the early season. GS structures represented about 10% of the shoots in the lowest pruning trees and reached about 60% in the highest pruning trees (Fig. 2C). However, in the case of GS, the number of leaves per GS did not increase significantly with IP (cor=0.21, NS).
Aphid dynamics in relation with pruning and tree variables

The aphid infestation varied in a synchronous way among trees for both years, but differently between years (Fig. 3A and 3B).

Figure 2. (A) Seasonal shoot growth evolution of an average shoot of non-infested trees under low (LP), medium (MP) and high (HP) pruning intensity in 2006. LP: IP\(\leq 40\%\) (n=4), MP: 40\%<IP\(\leq 55\%\) (n=2), HP: IP>55\% (n=2), n is the number of trees per group of pruning intensity. Vertical bars represent the S.E. of group means. (B) Relationship between the average number of leaves per shoot and pruning intensity at the last date of monitoring in 2005 and 2006. non-I: non-infested trees, I: infested trees. (C) Proportion of rosettes-R- and growing shoots-GS- in relation to pruning intensity in 2005 and 2006.

Figure 3. Seasonal evolution of the index of relative infestation of infested trees in 2005 (A) and 2006 (B) under low (LP), medium (MP) and high (HP) pruning intensity. LP: IP\(\leq 40\%\) (n=6, n=3 in 2005 and 2006 respectively), MP: 40\%<IP\(\leq 55\%\) (n=3, n=3), HP: IP>55\% (n=3, n=4), n is the number of trees per group of pruning. Vertical bars represent the S.E. of group means. (C) Relationship between the maximal index of relative infestation and pruning intensity in 2005 and 2006. The arrow indicates the outlier removed from the analysis (this tree had a high proportion of GS and had the highest initial level of infestation).
In 2006, IF increased slowly and reached lower levels (p<5%) than in 2005. Different hypotheses are proposed to explain this difference: presence of earwigs *Forficula auricularia* L, lower quantity of inoculums or/and unfavourable climatic conditions (wind, low temperatures) at the early season. Except 2 trees at the border of the insect proof shelter, earwigs abundance was similar between trees. These 2 trees were not considered in the study. The decrease of aphid population, just after the peak, could be explained by the following reasons:

- high levels of winged aphids (the percentage of infested shoot with at least one winged form was maximal at 145 JD for 2005 and 178 JD for 2006, regardless of the infestation levels)
- fall of infested leaves, which occurred around 130 to 150 JD for 2005 and 160 to 180 JD for 2006.
- mortality due to high temperature at the end of June.

After the decline, a regrowth tendency was observed in 2005 but not in 2006. This maybe due to the fact that the decrease occurred late in the season in 2006.

Both in 2005 and 2006, the aphid population dynamics were affected by pruning: higher levels were reached with increasing IP (Fig. 3). Positive relationships between maximal IF and IP were significant in 2006 (R²=0.63, p<1%) and in 2005 (R²=0.36, p<5%), by removing one tree from the analysis (Fig. 3C). Positive relationships between IF and IP were recorded to be significant at 5% level, at 5 and 9 dates in 2005 and 2006 respectively. The proportion of infested shoots was significantly higher (chi2 test, p<0.1%) in GS type than R type at almost all dates. Moreover, the percentage of shoots that reached an infestation degree greater or equal 3 was significantly (chi2 test, p<0.1%) higher in GS type (46% in 2005, 25% in 2006) than in R type (9% in 2005, 4% in 2006).

**Figure 4.** (A) Seasonal shoot growth evolution of an average growing shoot of infested (I) and non-infested (non-I) trees in 2005. Vertical bars represent the S.E. of tree means. Boxplot distribution of the mean values per tree of fruit fresh mass (B) and refractometric index (C) of infested and non-infested trees in 2005.

**Effect of aphids on shoot growth and fruit quality**

At the beginning of the season, aphids did not affect shoot growth (expressed in number of leaves per shoot). Later, the number of leaves of infested trees decreased, due to a premature defoliation of curled leaves, and the apparent growth rate was negative (Fig 4A). In 2005, a
linear relationship was observed between the minimal value of growth rate and the maximal value of IF ($R^2=0.75$, $p<0.1\%$). The correlation between the proportion of curled leaves on shoots and IF showed a significant relationship ($R^2=0.57$, $p<0.1\%$). After leaves fall, the shoot growth rate of infested trees increased. Nevertheless, the number of leaves per shoot remained low compared with non-I trees (Fig. 4A). Moreover, the average shoot length of GS, measured at the end of the season, was significantly ($p<0.1\%$) lower in I treatment (9.73cm) than in non-I treatment (14.76cm) in 2005.

A close relationship between fresh fruit mass and fruit load was observed on the one hand, and between IR and fruit dry weight and water content on the other hand. The losses due to aphids were about 5% of fresh mass and 3% of refractometric index (Fig. 4B and 4C). However, these losses were not significantly different from zero (wilcoxon rank sum test, NS).

**Conclusion**

These results reinforced our choice to investigate winter pruning as a potential complementary method of aphid control in orchards since aphid population was reduced under low pruning treatments. This effect was mainly due to a decrease of the proportion of ‘growing shoots’, which were more favourable to aphid development. However, the wood rejuvenation capacity of new shoots (evaluated throughout their length) was reduced by low pruning, due to an increase of the proportion of ‘rosettes’. Therefore, the reduce of pruning to regulate aphid population has to integrate a negative effect on wood rejuvenation. On the other hand, in the case of our two-year study, our results did not support the view that peach trees needed to be totally protected from aphids since trees were able to support a certain level of aphids without important production losses. With the increase of winged forms, the aphid population decreased naturally. Therefore, the improvement of aphid management requires to define precisely the relationship between the aphid level and the production damage and to consider the seasonal aspect of aphid dynamics.

Our results identified some interactions between peach tree and aphids and underlined the necessity to consider the system on an integrated way. In the near future, these data will be used to develop a model of the system in order to improve IFP strategies.

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Predicting the risk of post harvest rot on peaches

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Abstract: Knowledge of the risk of post-harvest rot in batches of peaches can enable distribution channels to be chosen accordingly. Ctifl is developing a test that will predict the risk of contamination of fruit at harvest and during storage. This technique consists in collecting a sample of fruit about one week before the first picking and placing it in conditions conducive to the development of rot. This provides an indication of the storage potential after one or two weeks of observation. We observed a good correlation between the predictive test and monitoring disease development on samples collected at harvest.

Keywords: Peach, fungal pathogen, brown rot, storage disease, post harvest

Introduction

Storage rot of peaches is mainly due to brown rot (Montilia laxa, fructicola, fructigena). Fruit contamination usually takes place in the orchard. Sporulation does not take place in darkened cold store rooms, so contamination of fruit can only take place through contact with infected fruit.

Chemical control measures in orchards cannot totally eradicate the risks of the disease infecting the crop. The level of infestation in a given plot has a strong influence on control efficacy, which is always preventive. However rots do not necessarily appear in the orchard and their absence does not always imply that the crop is disease-free, as damage can appear after fruit is harvested.

Knowledge of the risk of post-harvest rot is important for marketing, as the marketing channel can be chosen according to the risk of disease development on the fruit. With this in mind, a predictive test is presented which can evaluate the post harvest performance of fruit. The aim is to have information about this before harvest takes place.

Principle of the predictive test

It is accepted that fruit are contaminated in the orchard by brown rot conidia settling on the fruit whilst hanging on the tree. These conidia germinate when weather conditions are favorable (wetness on fruit surface): rain, dew, condensation when removed from cold storage. In the orchard, wet periods allow rots to develop on the tree and produce conidia which in turn increase the number of spores that contaminate other fruit. Once the spores have germinated, the filament of the fungal mycelium has to find a point of entrance on the surface of the skin (feeding punctures, rubbing injury, small splits…) the fungus cannot perforate the epidermis itself. Only when the fungus comes into contact with the flesh will rot develop.

The severity of post harvest rot is therefore dependant on:
- the quantity of spores (conidia) present on the fruit at harvest
- the incidence of skin damage (small splits…)
- fruit wetness
Materials and methods

The test described consists in collecting fruit samples from the orchard one week before the first picking and placing them in conditions that are favourable for conidia germination (3\textsuperscript{rd} point) to get an idea of the potential for rot development (1\textsuperscript{st} and 2\textsuperscript{nd} points).

Methodology

- 30 fruit samples are collected (2 trays with 15 individual cells) per plot.
- Dip fruit in water or spray water abundantly on the tray.
- The tray is hermetically wrapped in a plastic film to maintain a humid atmosphere.
- Stored at room temperature (22 to 26°C) under natural or artificial light 12/24hrs.
- Rotten fruit counted every 2-3 days. Ensure that fruit infected by *Rhizopus* are taken out, as fruit in adjoining cells can be infected in 24hrs, which will rapidly spread to the whole tray.
- Counting rotten fruit every 2-3 days will enable a curve to be established on rot development.

In our experiment, we compared these samples with batches taken from successive harvests (24 plots in 2000, 11 in 2001, 28 in 2002).

Samples were then collected during harvest and stored in the same conditions for rot development so that the results could be compared with the predictive test.

Results

The results from the test on rot development are coherent with those obtained from the majority of batches of harvested fruit (18 out of 24 in 2000, 7 out of 11 in 2001, 19 out of 28 in 2002).

Result interpretation must take weather conditions during harvest into account.

Figure 1 shows the type of situation on 2 plots when pest pressure is low.

![Figure 1](chart.png)

Figure 2 shows a plot with higher pest pressure. It is evident that in this type of situation the last two pickings show a rapid development in disease pressure due to the presence of rotten fruit in the orchard.
Figure 3 shows a similar situation in an orchard with very low pest pressure at the beginning of harvest. The level of rot (50%) at the 5th picking is lower than in the previous case (100%). The rate at which the fruit rot is also slower. Note that the reliability of the test decreases as time moves on from the sampling date (26 days between the sampling for the predictive test and the 5th picking presented in figure 3).
Figure 4 shows the example of when the predictive test did not give an indication of the potential of rot on the plot. This can be explained by weather conditions that were favourable for development of brown rot, that occurred between the sampling for the predictive test and the beginning of harvest. During this period, prolonged wetting periods of over 6 hours occurred on several days.

**Discussion**

This method can also be used during harvest to predict rot development in each plot on the farm. Problems can be anticipated and preventive measures can be taken. Figure 5 shows the case of 2 orchards with the same variety that behaves totally differently towards brown rot. In orchard A irrigation was moderate and drastic preventive measures were carried out, whereas in orchard B there is higher disease pressure and abundant irrigation.

![Figure 5](image)

This simple method remains to be validated by routine use on fruit farms. It seems to provide a good indication of storage potential of batches of peaches from a given plot. We have observed that the plot influences rot incidence; sometimes great differences exist in shelflife, even for fruit of the same variety.

**References**


Effect of cropping practices on brown rot in peach orchard

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Abstract: Irrigation schedules based on crop evapotranspiration or micromorphometric changes (pepista method), combined with conventional or manual pruning were tested on cv. Nectarross peaches. The effects of these treatments on brown rot were observed in 2003, 2004 and 2005. During the three years of trials, the first brown rot attacks appeared approximately three weeks before harvest. Between three weeks and one week before harvest, brown rot attacks were significantly higher with conventional pruning than with manual pruning, and there was no difference due to irrigation treatments. The last week before harvest, there were more brown rot attacks on fruits irrigated with the crop evaporation monitoring system than with pepista. The counting of infected fruits carried out on the whole tree at harvest confirmed results observed during the monitoring of a fruit sample. The post-harvest monitoring showed that fruits treated with manual pruning combined with pepista irrigation developed significantly less rots than fruits treated with the other combinations.

Keywords: cropping practices, brown rot, peach

Introduction

In the Middle Rhône Valley, brown rot were caused by three Monilinia species, Monilinia fructigena and Monilinia laxa and more recently Monilinia fructicola, quarantine pest at the European Union. The damage on fruits or in storage is due primarily to the 2 last species (Mercier et al., 2003).

The cropping practices influence the development of brown rot. Thus, Arnoux (1981) shows that according to the mineral nutrition of the tree, the attacks of brown rot are expressed differently. Studies carried out in the French technical organizations indicate that a too abundant irrigation causes an increase in the rots on fruits (Chamet and Cotte, 1998; Blanc et al., 2002). In the same way in our unquestionable observations technical farming seem to play an important part on the damage of brown rot in an indirect way either by reducing the entrance doors (microscopic cracks) on the fruits necessary for the penetration of the spores of brown rot : reasoning of the irrigation or to improve the microclimate of the tree (manual pruning which possibly to increases the porosity of the crown). These are the 2 techniques which will be the subject of our study with for goal initially to give precise answers to the professionals and in the second time to feed a model describing the epidemics of brown rot (decision-making aid tool).

Material and methods

Orchard description

This study was carried out in a peach tree orchard planted in 2000 at the Gotheron Experimental Station of the Institut National de la Recherche Agronomique near Valence in the Middle Rhône Valley in France.
The area of the experimental orchard was 0.35 ha. Nectaross, a late maturing nectarine (Prunus persica (L.) Batsch) cultivar, grown on GF305 rootstock, was planted in an open vase training system (4 x 5 m). Approximate dates of flowering, beginning of stages II and III, and harvest were 20 March, 10 June, 10 July and 10 August, respectively.

Weeds in the tree row were controlled manually by hoeing in the first year, and with one application of napropamide and further seasonal applications of paraquat, when needed in subsequent years. Rye grass was sown between rows to provide permanent ground cover. Full bloom occurred on 15, 20 and 25 March in 2003, 2004 and 2005, respectively. Hand-thinning was carried out in May to give fruit spaced 10 to 15 cm apart along the fruiting shoots in order to ensure suitable fruit size (Mitcham, 1980). Crop phytoprotection was managed according to the Integrated Pest Management devices (Sansavini, 1997). But no phytoprotection was applied against brown rot in order to observe the effect of water management and pruning on this peach disease incidence.

A microjet irrigation system was installed with 2 emitters per tree, in a distance of 1m from the tree. Each emitter had a discharge rate of 30 l.h\(^{-1}\). Rainfall was measured on the site (ca. 800 mm in average for the 10 last years) and ETo calculated using Penman equation.

**Experimental arrangement and analysis**

In 2003, at the differentiation of the treatments, the homogeneity of the experimental area was checked by measuring tree trunk circumference. The experiments were performed on four tree rows, the five other tree rows being taken as guard rows. The combination of cropping practices: pruning (conventional or early manual pruning of the vegetative shoot) and irrigation schedules (crop evapotranspiration or micromorphometric changes, PEPISTA® Method) on brown were compared. These four treatments were disposed in four blocks. Each experimental unit comprised five trees.

Manual pruning derives from apple tree centrifugal training and it is currently tested in a qualitative aim of the fruit, by south of France farmers with INRA assistance (Navarro and Plénet, 2002). It consists, in April, to remove all the shoot of the base until the 1/3 of the secondary branches and the most vigorous shoot on the top of the secondary branches. The Pepista method, developed by INRA precisely determines the irrigation requirements for the plant thanks to sensors micromorphometric placed directly on the secondary branches (Huguet et al., 1992).

A classical analysis of variance was used for the statistical analysis of these data (Dagnelie, 1975). The LSD test was performed for average discrimination (Statgraphics® Plus software).

**Assessment of brown rot development**

Three controls was carried out for precisely quantify development of brown rot on fruits:

- **Epidemics of brown rot before harvest.** Disease was assessed twice weekly by counting the number of fruits that showed symptoms of brown rot on fruits sample on three trees. The assessment started when brown rot was first observed on attached fruits and continued until harvest. The samples of fruits were constituted of about five fruits on ten branches on three trees. In these samples, individual fruits with brown rot were removed from the tree.

- **Incidence of brown rot on harvest.** The number of fruits that showed symptoms of brown rot was counted on all the fruits on the same three trees at the first pick. Individual fruits with brown rot removed in precedent sample were added.

- **Assessment in storage.** On these three trees, 42 and 28 fruits without symptom of brown rot and no visible injury in 2003 and 2004 respectively were removed on first pick and were precociously disposed, in order to prevent any damage, in fruitboards equipped with
wadding alveolus. These fruits were assessment daily and fruits that showed symptoms of brown rot were counted and removed.

**Agronomic performances**

Fruit yield was determined at harvest of each experimental unit. The harvest was achieved in 3 pickings, and the fruits were selected at the orchard to differentiate them according to the marketable standard used in the area: the damaged fruit were recorded as second-class fruit, as opposed to first-class fruit commercially well-suited. Average fruit weights were calculated on a representative sample of the fruit production (about 20% of the total harvest). In 2005, relative euros/ha returns were calculated considering tree yield, fruit size distribution and fruit marketable class in the central sampled trees. These peach field prices (Lorifruit Cooperative) were for comparison only and did not account for production costs.

Figure 1. The cumulative percentage of fruits showing symptoms of brown rot. Treatments: ETP = crop evapotranspiration, CP = conventional pruning, MP = manual pruning, PM = micromorphometric changes (Pepista method). Each data point represents the mean of 4 replicates except in 2003 there is no replication. Bars indicate the standard errors.
Results

Before harvest
During the three years of trials, the first brown rot attacks appeared approximately three weeks before harvest (Figure 1). Between three weeks and one week before harvest, brown rot attacks were significantly higher with conventional pruning than with manual pruning (e.g. 5.7% against 2% 10 days before harvest in 2004), and there was no difference due to irrigation treatments. The last week before harvest, there were more brown rot attacks on fruits irrigated with the crop evaporation monitoring system than with pepista method (e.g. 14% versus 8.5% 2 days before harvest in 2004).

Figure 2. Percentage of fruits showing symptoms of brown rot at harvest. Treatments: ETP = crop evapotranspiration, CP = conventional pruning, MP = manual pruning, PM = micromorphometric changes (Pepista method). Different letters indicate significative differences group according LSD test, P=0.05.
**At harvest**
The counting of infected fruits carried out on the whole tree at harvest confirmed results observed during the monitoring of a fruit sample (Figure 2). More innovative cropping practices, Pepista Method and manual pruning reduced incidence of brown rot compared to the most used cropping practices, evapotranspiration and conventional pruning. The reduction of brown rot attacks was 82.4 %, 64.3 % and 69.2 % in 2003, 2004 and 2005, respectively.

**In postharvest**
Results of storage monitoring was the same: the most used cropping practices, evapotranspiration and conventional pruning had a significantly greater incidence than more innovating cropping practices, Pepista Method and manual pruning for all assessments in 2003 and in 2004 (Figure 3).

![Figure 3](image)

**Agronomic performances**
Fruit yield did not significantly differ according to the 4 treatments (Fig. 4A). Nevertheless, more innovating cropping practices (PM-MP) had significant lower average fruit weight at
harvest (Fig. 4B). Furthermore, relative monetary return tended to increase (+23%) under PM, compared to ETP (Fig 4C).

![Graph showing total yield per tree, average fruit weights at harvest, and monetary returns.](image)

Figure 4. A) Total yield per tree, B) Average fruit weights at harvest and C) Monetary returns in 2004. Different letters indicate significant differences group according LSD test, P=0.05.

**Discussion**

These results showed that one should not limit the protection against the brown rot to use of the plant health products. The use of several techniques complementary to the phyto protection can allow decreasing the brown rot attacks in orchard and in storage conditions. That was demonstrated by the significant results obtained in this study, without use of fungicidal protection against the brown rot. Assumptions can be put forth to explain these results. The manual pruning practice possibly increases the sunning within the tree. This microclimatic change possibly acted mainly on the induction and germination of the conidia (Wilcox, 1989; Tamm & Fluckiger, 1993). In our orchard, the use of Pepista led to delay the release of the irrigation and to decrease the contributions of water. The diameter of the fruits to harvest in this method is a little smaller than in the crop evapotranspiration assessment but the sugar contents are a little higher. One can suppose that these fruits present less cracks on the skin and thus less entrance doors for the conidia of brown rot present in the orchard.
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