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List of Participants

BERRIE Angela
H.R.I. East Malling
West Malling
Kent ME19 6BJ
UK
angela.berrie@hri.ac.uk

BIELENIN Anna
Research Institute of Pomology & Floriculture
Pomologizna 18 str.
Skierniewice 96-100
Poland
abielen@insad.pl

BYLEMANS Dany
RSF, Research Station of Gorsem
De Brede Akker 13
B-3800 Sint-Truiden
Belgium
dany.bleynants@ping.be

CABALERIO Cristina
Escola Politecnica Superior
Department de Produccion Vaxetal
Universidade de Santiago de Compostela
Campus de Lugo s/n 27002 LUGO
Spain
pvcabsob@lugo.usc.es

CROSS Jerry
H.R.I. East Malling
West Malling
Kent ME19 6BJ
UK
jerry.cross@hri.ac.uk

DAUGAARD Holger
Danish Institute of Agricultural Sciences
Kirstinebjergvej 10
Aarslev
DK-5792
Denmark
Holger.Daugaard@agrsci.dk

DUNCAN James
Scottish Crop Research Institute Invergowrie
Dundee DD2 5DA
UK
jdunca@scri.sari.ac.uk

EIKEMO Haavard
The Norwegian Crop Research Institute
Hoegskolvent 7
N-1432 Aas
Norway
haavard.eikemo@planteforsk.no

FENTON Brian
Scottish Crop Research Institute
Invergowrie
Dundee DD2 5DA
UK
b.fenton@scri.sari.ac.uk

FITZGERALD Jean
H.R.I. East Malling
West Malling
Kent ME19 6BJ
UK
jean.fitzgerald@hri.ac.uk

GAJEK Dariusz
Research Institute of Pomology & Floriculture
Pomologizna 18 str.
96-100
Poland
dgajek@insad.pl

GORDON Stuart
Scottish Crop Research Institute
Invergowrie
Dundee DD2 5DA
UK
sc.gordon@scri.sari.ac.uk

GRASSI Alberto
Instituto Agrario Di S. Michele all’Adige
Via Edmundo Mach No 1
S. Michele a/Adige
Trentino
Italy
Alberto.Grassi@mail.ismaa.it

HARDEN Richard
KG Fruits Ltd
15 Commercial Road
Paddock Wood TN12 6EN
Kent, UK
rharden@kgfruits.com
ISSACS Rufus  
209 Center for Integrated Plant Systems  
Michigan State University  
East Lansing  
MI 48824  
USA  
isaacsr@msu.edu

JENNINGS Nikki  
Scottish Crop Research Institute  
Invergowrie  
Dundee DD2 5DA  
UK  
sjenni@scri.sari.ac.uk

JÖRG Erich  
Landesanstalt für Pflanzenbau und Pflanzenschutz  
Essenheimer str 144  
D-55128 Mainz  
Germany  
ejoerg.lpp-mainz@agrarinforlp.de

JONES Graeme  
Horticultural Development Council  
Bradbourne House  
East Malling ME19 6DZ  
Kent, UK  
Graeme.Jones@hdc.org.uk

JONES Teifion  
Scottish Crop Research Institute  
Invergowrie  
Dundee DD2 5DA  
UK  
t.jones@scri.sari.ac.uk

ŁABANOWSKA Barbara  
Research Institute of Pomology & Floriculture  
Pomologizna 18 str.  
Skierniewice 96-100  
Poland  
blabanow@insad.pl

LISEK Jerzy  
Research Institute of Pomology & Floriculture  
Pomologizna 18 str.  
Skierniewice 96-100  
Poland  
jlisek@insad.pl

LINDER Christian  
Swiss Federal Research Station for Plant Protection  
RAC-Changis  
CH-1260 Nyon  
Switzerland  
christian.linder@rac.admin.ch

LOLA-LUZ Dora  
Teagasc  
Soft Fruit Centre  
Clonroche  
Co. Wexford  
Ireland  
tlolaluz@clonroche.teagasc.ie

MALLOCH Gaynor  
Scottish Crop Research Institute  
Invergowrie  
Dundee DD2 5DA  
UK  
gmallo@scri.sari.ac.uk

MESZKA Beata  
Research Institute of Pomology & Floriculture  
Pomologizna 18 str.  
Skierniewice 96-100  
Poland  
bmeszka@insad.pl

MILENKOVIĆ Slobodan  
ARI "Serbia" Fruit and Grape Research Centre  
32000 Serbia  
centarca@eunet.yu

NORHTCROFT David  
KG Fruits Ltd  
15 Commercial Road  
Paddock Wood TN12 6EN  
Kent  
UK  
dnorthcroft@kgfruits.com

OLSZAK Remigiusz  
Research Institute of Pomology & Floriculture  
Pomologizna 18 str.  
Skierniewice 96-100  
Poland  
rolszak@insad.pl
SIMPSON Robert
Angus Fruits Ltd
East Seaton
Arbroath DD11 5SD
UK
ra.simpson@virgin.net

SMITH Veronica
SEERAD
R342b Pentland House
47 Robbs Loan
Edinburgh EH14 1TY
UK
veronica.smith@scotland.gsi.gov.uk

STROMENG Gunn-Mari
The Norwegian Crop Research Institute
Hoegskolveien 7
N-1432 Aas
Norway
gunn-mari.stromeng@planteforsk.no

SZANTONE-VELSZELKA Maria
Plant Protection and Soil Conservation
Service of Nograd County
H-2662 Balassagyarmat
Hungary
nta-nograd@fki.gov.hu

SZENDRY Gabriella
Plant Protection and Soil Conservation
Service of Heves County
Eger
Szovetkezet ut. 6
Hungary
nta-heves@fki.gov.hu

TORNEUS Christer
Swedish Board of Agriculture
Box 12
230 53 Alnarp
Sweden
christer.torneus@sjv.se

TRANDEM Nina
The Norwegian Crop Research Institute
Hoegskolveien 7
N-1432 Aas
Norway
nina.trandem@planteforsk.no

WOODFORD Trefor
Scottish Crop Research Institute
Invergowrie
Dundee DD2 5DA
UK
t.woodford@scri.sari.ac.uk

WILLIAMSON Brian
Scottish Crop Research Institute
Invergowrie
Dundee DD2 5DA
UK
b.williamson@scri.sari.ac.uk
Status of Integrated Production of Soft Fruit in Europe

Dariusz Gajek¹, Erich Jörg²
¹Research Institute of Pomology and Floriculture, Pomologiczna 18, PL-96-100 Skierniewice, Poland
²Landesanstalt für Pflanzenbau und Pflanzenschutz, Essenheimerstr. 144, D-55128 Mainz, Germany

In cooperation with:
J. Avilla, J.M.T.Balkhoven-Baart, A. Berrie, G. Bouwman, J.V. Cross, H. Daugaard, M. Edin,
A. Grassi, H. Koenraads, Sz. Laszlone, V. Laugale, S. Milenkovic, I. Morocko, N. Neuweiler,
R. Steffek, M. Szantone Veszelka, Ch. Torneus, N. Trandem, F. Vega,

Abstract: A survey on soft fruit production in several countries and regions of Europe was carried out in 2001 with respect to aspects of Integrated Production. Data on area of various soft fruit crops grown according to standard and integrated production rules, numbers of growers, usage of biological and biotechnical control measures, availability of plant protection products and the main problems of implementation of Integrated Production into practice were collected. It proved that IP or quality assurance schemes were operated in most of the investigated countries. The total production area of these crops included under IP rules was small. None of elaborated national (or regional) guidelines was fully in compliance with IOBC/WPRS IP - Guidelines for soft fruits. Differences in requirements for soil management, plant nutrition as well as crop protection and control procedures were noticed. Among the main problems of Integrated Production of soft fruits the control measures of pests and diseases, a lack of resistant/tolerant cultivars, poor pesticide availability and unsatisfactory cooperation between institutions or organizations involved in soft fruit production were most important. In comparison with an earlier survey carried out in 1995 a considerable improvement of the status of Integrated Production cannot be ascertained. International co-operation is needed to concentrate the limited resources on elaborating solutions for the most striking problems.

Key words: soft fruits, integrated production

Introduction

Soft fruit is a multifarious and specialized branch of fruit production, which is constantly developing throughout Europe. A higher profitability of some soft fruit compared to pome and stone fruit crops leads to increased intensification and, very often, in the area of production. This simultaneously creates new, various and uncommonly severe problems, related also with integrated or organic production of these crops. The results of a previous analysis of the status of integrated production of soft fruits were presented during IOBC – Conference at Cedzyna (Poland) in 1995 (Cravedi and Joerg, 1996). Many failings and gaps as well as promising aspects of this field were identified there. To establish and develop an Integrated Soft Fruit Production in Europe the IOBC Guidelines were elaborated and published in 2000 (IOBC/wprs Bulletin 23 (5), 2000). An intention of this paper was to identify the actual progress in developing and implementation of IP for soft fruits in Europe.

Survey

The model of the survey was taken after the example of Cross et al. (1996). The survey was carried out in 2001 by e-mail or by a postal questionnaire sent to representatives from
different countries or regions of Europe. In some cases the responses received were not completed, or their scientific interpretation was not possible, and then the data were marked as not available.

**Standard and integrated production of soft fruit in Europe**

The collected data have shown that soft fruit production constitutes an important branch of horticulture in many regions of Europe (Table 1). Poland is the European leader of this production. The area of production and the number of growers of strawberry, currants and gooseberry are the highest in this country. In case of strawberry, Germany and Yugoslavia have large areas of production. In the Andalucia region of Spain, strawberry covers an area of 800 hectares. France and The Netherlands are also large producers of strawberries but the supporting data illustrating that is not available. Currants, mainly blackcurrants, are grown on a large scale in Poland as well as Hungary and Germany. The same countries are also the main producers of gooseberry. According to responses received distinctly the greatest production of cane fruits is in the former Yugoslavia. Other significant producers of these fruits are Poland and France. Among other soft fruit crops grown in Europe elderberry, blueberry and kiwi have to be mentioned. A special attention should be paid on production area of elderberry in Austria and Germany. Moreover, the area of blueberry production is increasing rapidly in Poland.

Table 1. Soft fruit production in some European countries or regions in 2001

<table>
<thead>
<tr>
<th>Country or region</th>
<th>Crop</th>
<th>Joint area of field and protected production (ha) / Number of growers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strawberry</td>
<td>Currants</td>
</tr>
<tr>
<td>Austria</td>
<td>1222/552</td>
<td>220/531</td>
</tr>
<tr>
<td>Belgium</td>
<td>2471/1023</td>
<td>112/789</td>
</tr>
<tr>
<td>Denmark</td>
<td>991/568</td>
<td>1411/210</td>
</tr>
<tr>
<td>France</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>8420/3000</td>
<td>1185/1156</td>
</tr>
<tr>
<td>Latvia</td>
<td>1000/300</td>
<td>600/100</td>
</tr>
<tr>
<td>Nederland</td>
<td>750/n.a.</td>
<td>20/n.a.</td>
</tr>
<tr>
<td>Norway</td>
<td>1602/1250</td>
<td>270/300</td>
</tr>
<tr>
<td>Poland</td>
<td>50000/250000</td>
<td>33000/30000</td>
</tr>
<tr>
<td>Sweden</td>
<td>2800/770</td>
<td>415/186</td>
</tr>
<tr>
<td>UK</td>
<td>3341/300</td>
<td>1458/208</td>
</tr>
<tr>
<td>Yugoslavia</td>
<td>8100/19000</td>
<td>60/n.a.</td>
</tr>
<tr>
<td>Andalucia (Spain)</td>
<td>800/1200</td>
<td></td>
</tr>
<tr>
<td>Trentino (Italy)</td>
<td>97/n.a.</td>
<td></td>
</tr>
</tbody>
</table>

<sup>*n.a. – not available; a – elderberry; b – blueberry; c - kiwi</sup>
Although soft fruit crops play an important role in whole fruit production of many European countries, the IP rules for these crops are not widely applied. The exception may only be the United Kingdom where the Assured Produce Scheme (APS) was adopted in great measure (this is related to IP). Regarding to particular soft fruit crops the results of the survey show the largest implementation of these methods in strawberry growing (Table 2). In the United Kingdom more than 60% of the area of this crop is reported to be grown according to the Assured Produce Scheme. Another example is the region of Andalucia in Spain where 442 growers conduct IP of this crop on an area of 2800 ha. IP of strawberry is also implemented in such countries like Germany, Sweden, Poland Denmark and Italy, but scale of this production is much smaller than in countries mentioned above. In comparison with strawberry the extent of IP schemes for other soft fruit crops is even worse. The great quantity of raspberry is produced according to IP rules only in Yugoslavia and France, whereas UK is a leader of APS implementation onto bush crops (Table 2). The examples of other countries show the unsatisfactory state of these practices.

<table>
<thead>
<tr>
<th>Country or region</th>
<th>Joint area of field and protected production (ha) / Number of growers</th>
<th>Crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>147/27</td>
<td>Strawberry</td>
</tr>
<tr>
<td>700^b / n.a.</td>
<td>Other</td>
<td>Other</td>
</tr>
<tr>
<td>France</td>
<td>1955/86</td>
<td>71^a, 10^b, 46^c, 19^d / 32</td>
</tr>
<tr>
<td>Germany</td>
<td>240/66</td>
<td>62^a / 20</td>
</tr>
<tr>
<td>Poland</td>
<td>440/65</td>
<td>1537^a, 702^b / 250</td>
</tr>
<tr>
<td>Sweden</td>
<td>2222/271</td>
<td>2500^b, 3^d / 8001</td>
</tr>
<tr>
<td>UK</td>
<td>2800/442</td>
<td>33^a, 46^b, 40^d / 1400</td>
</tr>
<tr>
<td>Yugoslavia</td>
<td>97/n.a.</td>
<td></td>
</tr>
</tbody>
</table>

a – currants and gooseberry, b – cane crops, c – elderberry, d - blueberry

**Table 2. Integrated soft fruit production in some European countries or regions in 2001**

**Availability of IP guidelines for soft fruits and their compliance with IOBC Guidelines**

The survey also showed that IP guidelines for soft fruits have operated in most of the investigated countries. Some of these guidelines were elaborated just at the beginning of nineties, for example in Trentino (Table 3). IP guidelines of other countries/regions have been enacted after IOBC Euro-guidelines (IOBC wprs Bulletin Vol. 23 (5) 2000), for example IP of strawberry in Austria and Denmark, IP of raspberry in France or IP of blackcurrant in Poland. Considering this fact it seemed that especially these principles should closely comply with European standards. Putting aside an activation term, an investigation showed that none of elaborated national (or regional) guidelines have been fully in compliance with requirements of IOBC Guidelines and, depending on representatives, many various differences were identified. In several countries major differences or obstacles occurred in relation to the availability of IPM suitable chemicals. This problem has been widely discussed in other papers in this volume (e.g. Galli et al. and Umpelby).
Other important divergences referred to the soil management, plant nutrition or irrigation requirements and, although lower standards compared to IOBC Guidelines were mainly mentioned, higher ones were also noticed. In some cases IP schemes permit to carry out the soil and plant chemical analyses every 5 years only or this procedure is not requested at all. The examples of the lower standards reported can also be no particular restrictions to the use of irrigation water, no indications about alleyways or an admission of soil sterilization whereas requirement that the water for strawberry irrigation must be the standard of drinking water is an example of higher standard.

The varied differences in plant protection and fruit management requirements were also ascertained. For example some IP guidelines require to make a strategy for plant protection prior to the season and conduct disease and pest monitoring / recording every 2 weeks. Others have no indication of at least 2 natural enemies per crop to preserve or even no clear pressure to use of monitoring practices is regarded.

IOBC Euro-guidelines indicates that a representative sample of at least 20% of farms must be visited at least once during the growing season. Unfortunately, the survey showed differences also in this matter. According to representatives of several countries, the percentage of farms visited is usually lower and often ranges from 10 to 5 %. There was an example of one country only whose guidelines require higher standard of control procedure and all farms must be controlled once every year.

Table 3. Availability of IP guidelines for soft fruits in some European countries or regions

<table>
<thead>
<tr>
<th>Country or region</th>
<th>Year of elaboration</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strawberry</td>
<td>Bush crops</td>
<td>Cane crops</td>
<td>Blueberry</td>
<td>Elder</td>
</tr>
<tr>
<td>Austria</td>
<td>2001</td>
<td>1995</td>
<td>1995</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Denmark</td>
<td>2001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>2001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>1999</td>
<td>1999</td>
<td>1999</td>
<td>1999</td>
<td>1999</td>
</tr>
<tr>
<td>Poland</td>
<td>1996</td>
<td>2001</td>
<td></td>
<td>1999</td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>1999</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Andalucia (Sp)</td>
<td>2000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 – raspberry; 2 - blackcurrant

**Threshold or forecasting models introduced into IP practice**

One of the most important problems of IP implementation into soft fruits is the limited range of detailed, workable threshold or forecasting models for the main pests or diseases. Conducted investigation confirmed a large gap of this issue but some promising points were also recorded. Most of them related to plant protection schemes of the strawberry crop where IP methods are most advanced. In case of strawberry pests, threshold of forecasting models for *Tetranychus urticae, Tarsonemus pallidus fragariae, Anthonomus rubi, Frankiniella occidentalis* and *Lygus rugulipennis* are introduced in some countries. In controlling such strawberry diseases like *Verticillium, Mycosphaerella fragariae, Xanthomonas fragariae* or *Anthracnose*, some development of these practices is also observed. Several examples of threshold or forecasting models concerned blackcurrant pests. Among them *Cecidophyopsis*...
ribis, Tetranychus urticae, Senanthedon tipuliformis, Lampronia capitella and midges were mentioned. Considering IP of raspberry, there is less development of monitoring and forecasting but in some countries monitoring for Tetranychus urticae, Resseliella theobaldi (and the associated Midge Blight) and Phytophthora disease were quoted. Threshold or forecasting models for pests / diseases of other soft fruit crops were not identified.

**Recommended biological and biotechnical control measures.**

According to the result of investigation the exploitation of predatory mites is the most frequent among biological control measures applied in IP of soft fruits. Other successfully used expedients are pheromone traps for Synanthedon sp. or sticky traps for Byturus sp. monitoring (see Woodford et al., this volume). A very effective biological control of root nematodes by growing certain Tagetes species is also promoted in some countries. Moreover, highly promising results in the control of the soft fruit leafrollers (Tortricidae) are obtained by using entomopathogenic bacteria - Bacillus thuringiensis. Similarly, entomopathogenic nematodes were found to be effective in the control of Otiorhynchus sp. however, acceptance of this treatment in practice is restricted because of economic reasons. Another example applied is disinfection with hot water in strawberry propagation.

**Cultivars resistant / tolerant to pests or diseases**

There are still a few possibilities to introduce into the practice the soft fruit cultivars resistant / tolerant to pests or diseases so highly susceptible cultivars still dominate in many regions at present. In case of the soft fruit pests the only examples were blackcurrant varieties resistant to the gall mite and raspberry varieties resistant to the cane midges. Among fungal diseases strawberry and raspberry cultivars resistant to Phytophthora, strawberry cultivars resistant to Botrytis and Sphaerotheca and also gooseberry and currants cultivars resistant to Sphaerotheca mors-uvae were found to be recommended for growing.

**The main problems of IP of soft fruits at present – challenges for the future**

Summarizing an overview of the most important aspects of the integrated production of soft fruits, it must be ascertained that the poor state of these practices is presently observed. Several important problems restraining the development of these methods throughout Europe are evident. First of all there is a big gap in the availability of plant protection products suitable for IP in many countries (see Galli et al., this volume, Gordon et al., 1997). Our knowledge on the possibility of biological pest or disease control also must be extended. The valuable exception in this matter is the satisfactory use of phytoseiid mites in some crops. Presented data showed also the lack of threshold values. Only a few elaborated monitoring or forecasting models for the main soft fruit pests and diseases have been introduced into practice.

Another obstacle to spread of these production methods is the small range of cultivars resistant to soft fruit pests or diseases. Although such cultivars are available they often lack sufficient yield or fruit quality to satisfy the supermarkets, processors or marketing organisations. The problem of many regions is also the structure of the farms. Frequently they comprise of many small plantations that prevents adequate control and inspection procedures. In some case the attitude of farmers to integrated production should also be changed. All problems mentioned above are simultaneously the main challenges for both scientists and extension workers in the future.

**References**


The role of certification schemes in integrated crop management of soft fruit in Scotland

Veronica V. Smith
SEERAD, R324b Pentland House, 47 Robbs Loan, Edinburgh, EH14 1TY, Scotland, UK.

Abstract: Scotland has a long history of soft fruit production particularly of raspberries and due to commercial demand the Scottish Plant Health Services introduced certification schemes for soft fruit plants in the 1930s. These schemes are still in use and are currently operated by The Scottish Executive Environment and Rural Affairs Department (SEERAD). The aims of the schemes are to provide fruit producers and propagators with planting material of a known health standard and purity and provide a means of preventing the spread of harmful pests and diseases. With the regular introduction of pathogen tested nuclear stock material, an unbroken history of certification and by limiting the time stocks can remain eligible for certification the health of fruit stocks can be maintained. Stocks can be certified at Foundation, Super Elite, Elite and Standard grade. SEERAD officers will verify the eligibility of all stocks entered for certification and inspect stocks to the standards of health, purity and separation specified for each grade.

Key words: raspberry, Rubus idaeus, high health stocks

Introduction

It has long been recognised that the vegetative propagation of crops can lead to the multiplication of both economically harmful pest and disease and of rogues (Ebbels 1979). The introduction of certification schemes by Plant Health Authorities was seen as a means of increasing productivity of crops by ensuring planting material was inspected and certified to a defined health standard and purity. In Scotland the first certification scheme to be introduced was for potatoes in 1918 in response to wart disease. The success of this scheme led to similar schemes for soft fruit in 1929, 1930, 1936 and narcissus in 1969.

History of soft fruit certification in Scotland

The first soft fruit certification scheme introduced by the Department of Agriculture for Scotland was of blackcurrants in 1929 (Anon. 1929). This was due to the concerns regarding purity and the spread of big bud and reversion and followed a similar scheme introduced in England and Wales in 1927. Inspection was limited to trueness to type and apparent freedom from reversion and at this time stocks would be entered from fruiting plantations. In 1929, seven applications were received from growers for approximately 187000 bushes of which 100000 failed due to reversion (Anon. 1929).

A scheme for raspberries followed in 1930 (Anon. 1930) and inspection was limited to trueness to type and apparent vigour and health at the time of inspection. In 1936, following a recommendation of the Scottish Horticultural Advisory Committee, a scheme was introduced for strawberry plants (Anon. 1936). Plants were inspected for trueness to type and freedom from serious disease over two successive years prior to certification. This was as a result of the concern of the ‘Lanarkshire Disease’, red-core, which was first recorded in Scotland in
1921. The causal fungi *Phytophthora fragariae* was not identified until 1940 by Hickman (Foister 1961).

The concerns of the spread of reversion and red-core led to the Sale of Strawberry Plants and Blackcurrant Bushes (Scotland) Order of 1947. This meant that the sale of uncertified plants was prohibited. As a result the health of propagating material vastly improved (Foister 1961). Blackcurrant propagating material had to be free from visible symptoms of reversion and be separated by 50 yards from any stocks showing reversion. Similarly strawberry runner plantations could only be certified if the plants were free from red-core, planted on land with no history of red-core and separated from red-core infected land which constituted a risk to the stock.

The economic future of the Scottish raspberry industry was threatened in the 1930s by the unchecked spread of virus diseases that were often difficult to detect visually (Anon. 1952). In 1944 a search began for a virus-free selection of Lloyd George which culminated in the import of 90 canes from New Zealand in 1946 (Harris and Cadman 1949). The further development of virus testing led to the use of pathogen tested stocks within certification schemes as a means to control soft fruit diseases (Ebbels 1979). With the regular introduction of pathogen tested nuclear stock material, an unbroken history of certification and by limiting the time stocks can remain eligible for certification the health of fruit stocks could be maintained. In 1953 growers throughout Britain formed a Nuclear Stock Association Ltd (NSA) to supervise the propagation and distribution of healthy fruit stocks from research stations.

In 1946 a system of strawberry runner-beds and raspberry spawn beds for propagation were developed (Ebbels 1979). This separated propagation from fruit production. However the certification of fruiting plantations in Scotland did not officially end until 1991 for strawberries, 1992 for raspberries and 1999 for blackcurrants, although in reality fruiting plantations were rarely entered.

In 1985 Raspberry Root Rot was identified for the first time in Scotland. Concerns regarding the spread of this disease led the Department of Agriculture to carry out a survey of fruiting plantations in 1989. 28% of holdings surveyed confirmed the presence of the disease with 75% of holdings in the Blairgowrie area affected. To prevent the spread of this disease The Soft Fruit Plants (Scotland) Order 1991 was introduced which ensured that only certified raspberries, strawberries and blackcurrants could be offered for sale and for raspberries, only certified stocks could be planted.

These statutory schemes for certified stocks were superseded by the EC Marketing of Fruit Plant Material Regulations 1995 which allowed for a minimum grade, CAC (Conformitas Agraria Communitatis) to be marketed within the European Union. Fruit plants were to be free of quarantine organisms and substantially free from other harmful organisms. However, as no definitive tolerance levels or inspection levels for harmful organisms were specified within the regulations, the CAC could be regarded as below the inspection standard of the certification schemes.

**Current certification scheme**

The current soft fruit certification schemes are based on the European Plant Protection Organisation (EPPO) recommendations (Anon. 1994). Nuclear Stock material is maintained in a protected environment at the Scottish Crop Research Institute (SCRI) and Horticultural Research International (HRI) and is tested for a wide range of pathogens. Material is released to approved propagators for certification at Foundation grade. Propagation can be
conventional or micropropagation and is carried out in a protected environment. Certification at Foundation grade is for one year only.

Foundation material is released for propagation at Super-Elite grade, which is normally the first stage of outdoor field-production. For all field grown stocks the propagator must ensure that the land in which the stocks are grown is free from Strawberry Red Core disease, Raspberry Root Rot disease and not subject to a notice regarding Wart Disease or Potato Cyst Nematode (PCN). Super-Elite stocks require the additional requirement of site approval by a SEERAD officer. The site is inspected prior to planting for isolation from wild soft-fruit stocks and fruiting plantations and sampled for freedom from PCN and free living nematodes responsible for virus spread.

Super-Elite stocks are purchased by propagators for further propagation at Elite and Standard grade. Each time certified stocks are sold for further propagation and certification they automatically drop a grade and stocks can only be certified if established from stocks of a higher grade. The health standard for the lower grades is less stringent than for higher grades, but for several important pests and diseases a nil tolerance is applied. Standard grade is usually released to fruit producers.

Stocks can only be certified at a certain grade for a stated period of time. This means that stocks released at Standard grade are at the most 6, 13 and 23 years removed from nuclear stock material of strawberries, raspberries and blackcurrants respectively. All stocks are inspected twice during the growing season and a third inspection is carried out in November for red-core disease on strawberries and big-bud on blackcurrants. Stocks may be sampled for testing for freedom from certain important diseases. If the stock does not meet the certification standard it drops to an appropriate lower grade, to CAC grade, or is rejected completely as propagation material.

The explanatory memorandum, which gives more detail of the standards for certification of soft fruit stocks, is available from SEERAD at the above address.

**Benefits of certification schemes**

Certification schemes play an important role in integrated crop management. By purchasing certified stocks, propagators and growers are initiating production from material of a known health standard and purity. Stocks that do not meet the prescribed standards for certification are unlikely to be used in propagation or commercial fruit production, which aids in the prevention of pest and disease spread. The regular introduction of pathogen tested nuclear stock material and limiting the time stocks can remain eligible for certification in each grade prevents the multiplication of systemic diseases to an uneconomic level. The isolation distances and the exacting standards required for the site in which they are grown help to ensure that the stocks remain healthy as long as possible. The propagator has an obvious role to play in ensuring that harmful pests and diseases are kept to a minimum.

Successful certification schemes adapt to changing circumstances as new economically important pests and diseases are discovered. Raspberry Root Rot, which was first identified in Scotland in 1985, was instantly recognised as a disease which required nil tolerance in a certification scheme. The increasing incidence of Strawberry Black Spot in Britain in the late 1980s led to SEERAD introducing petiole testing for all field-grown strawberry stocks. In addition, from 1993 propagators had to allow two rows in every stock to fruit so that a visual inspection for Black Spot could be carried out. In the early 1990s, Raspberry Bushy Dwarf Virus (RBDV) resistance breaking strain was first detected in Autumn Bliss in a commercial fruiting crop in Kent (Jones and Allen 1995). As a result of this new disease all raspberry spawn beds in Scotland entered for standard grade certification were sampled in 1994 and
1999 (Chard et al 2001) and proved negative for the virus. Any new introductions of stocks from outwith Scotland are tested routinely to ensure that propagating material remain free from this virus. These are just a few examples of an evolving certification scheme.

In conclusion, the importance of establishing fruiting stocks from certified material is recognised by Plant Health Authorities as a major means of reducing pest and disease spread and increasing the productivity of plants.

References

Development of Integrated Pest Management approaches for blackcurrant crops

J.V. Cross, A. Harris
Horticulture Research International, East Malling, West Malling, Kent ME19 6BJ UK

Abstract: Results of recent research at HRI-East Malling to develop IPM approaches for the most important pests of blackcurrant are summarised. A forecasting model for blackcurrant gall mite (Cecidophyopsis ribis) migration using daily maximum and minimum air temperatures was developed initially to improve the timing of acaricidal sprays for gall mite control. An experimental (5 x 5 Latin square) blackcurrant plantation was then established at HRI-East Malling in autumn 1999 with three varieties (in a split plot design) viz. Ben Hope (gall mite resistant), Ben Gairn (reversion virus resistant) and Ben Alder (susceptible). Five different insecticide/acaricide programmes are being applied as treatments: 1) 2 early sprays of sulphur at the start of gall mite migration to control gall mite 2) 2 sprays of sulphur + chlorpyrifos pre-flower to control gall mite and a wide range of insect pests 3) 2 sprays of sulphur + pirimicarb pre-flower to control gall mite and aphids 4) 3 sprays of fenpropathrin at the standard timings for gall mite control to control all pests 5) untreated control. This plantation is being used in a new three-year research project started in April 2000 to explore four objectives as follows:

• To determine whether host plant resistance to gall mite (in cv Ben Hope) or reversion virus disease (in cv Ben Gairn) combined with two early season sprays of sulphur (at the start of gall mite migration) can prevent gall mite and/or reversion virus infection under conditions of severe pest pressure. To determine the effects of such approaches on the natural enemies of other important pests.

• To determine the species compositions of the predatory mite fauna and how predatory and pest mite populations are affected by the IPM strategies for gall mite control.

• To determine whether the parasitoid Platygaster demades can be exploited as a natural enemy of blackcurrant leaf midge (Dasineura tetensi) and whether it is adversely affected by the IPM strategies for gall mite control or a pre-blossom spray of chlorpyrifos or pirimicarb.

• To characterise the natural enemy complex of the currant sowthistle aphid (Hyperomyzus lactucae) and to quantify levels of natural enemy attack in an IPM programme. Results to date indicate that combined use of host plant resistance and sulphur sprays may provide an effective strategy for gall mite and reversal virus management. Predatory mites, including Typhlodromus pyri, Neoseiulus californicus and N. finlandicus established and are potentially important natural enemies of spider mites in blackcurrant crops. The parasitoid Platygaster demades was found to parasitise blackcurrant leaf midge, though initial levels of parasitism were low (< 1%). Anthocorids and ladybirds were the most abundant aphid predators and are potentially important natural enemies of aphids in blackcurrant crops.

Key words: blackcurrant, gall mite, reversion, phytoseiid, spider mite, leaf midge, parasitoid, aphids, natural enemies

Introduction

Blackcurrant, Ribes nigrum, a long-term perennial crop, is subject to attack by a complex of insect and mite pests which attack different parts of the plant, several of which can cause significant economic loss. Until recently, pest control in blackcurrant crops has been by routine sprays of broad-spectrum insecticides, largely because of the need to control blackcurrant gall mite Cecidophyopsis ribis, the vector of reversion virus disease which
causes sterility in blackcurrant and which is the principal factor limiting the life of plantations. Prior to the advent of modern insecticides, lime sulphur was used for gall mite control. This was superseded by the organochlorine acaricide endosulfan in the 1950s. A programme of three sprays of endosulfan was routinely applied at fixed growth stages, the first just before flowering, the second at the end of flowering and the third 10-14 days later. This programme was moderately effective but broke down under conditions of high pest pressure, especially on highly susceptible varieties such as Ben Lomond and Ben Tirran. The acaricidal synthetic pyrethroid fenpropathrin was introduced as an alternative to endosulfan in the 1980s and has now replaced it since endosulfan has recently been withdrawn. Work in Denmark in the early 1990s showed that early season sprays of micronised sulphur are also moderately efficacious for gall mite control. Later applications are considered to be phytotoxic (Nielsen, 1987 a and b). It is now common practice in the UK to apply two such sulphur sprays; one at bud-break and one just before the first grape emerged growth stage. As a result, the number of growing season sprays of fenpropathrin is reduced where gall mite is absent. The fenpropathrin gives excellent control of some other pests, notably leaf midge, Dasineura tetensi, and caterpillars but is not very effective against aphids or capsids. Additional sprays of organophosphorus insecticides such as chlorpyrifos or of the aphicide pirimicarb are required usually before blossom. In addition, an intensive programme of fungicide sprays is applied against the important diseases mildew, leaf spot, Botrytis and rust. This intensive use of broad-spectrum pesticides has hitherto effectively prevented the development of Integrated Pest Management approaches for the crop.

However, an important recent development has been the release of two new blackcurrant varieties, one (Ben Gairn) resistant to the virus, the other (Ben Hope) resistant to the gall mite, bred at the Scottish Crop Research Institute. These varieties, which are presently only available to UK growers, are being planted on a rapidly increasing scale. It is estimated that they will comprise over 50% of the UK acreage in 5 years time. The advent of these new resistant varieties means that for the first time it may be possible to grow blackcurrants commercially without routine use of broad-spectrum insecticides. There is excellent opportunity to develop Integrated Pest Management approaches, which will result in substantially reduced use of pesticides (Cross and Easterbrook, 1998).

It is suspected that the gall mite or reversion resistances should not be relied on solely to prevent gall mite or virus infection. The use of one or two early season sprays of sulphur to protect the resistances needs to be investigated. Work in Poland by Niemczyk and his co-workers has suggested that predatory phytoseiid mites, including Typhlodromus pyri and Amblyseius sp., can regulate spider mite numbers effectively if populations of the predators are not disturbed by harmful applications of pesticides. The effectiveness of this mite management approach needs to be determined.

It is known that blackcurrant leaf midge, Dasineura tetensi, and aphids, especially the currant-sowthistle aphid, Hyperomyzus lactucae, are likely to be the major pest problems in blackcurrant crops not frequently sprayed with insecticides. The role and importance of natural enemies in naturally regulating these pests needs to determined. The parasitoid Platygaster demades is known to parasitise blackcurrant leaf midge larvae. In previous work on apple (Cross and Jay, 2001) the parasitoid was released into sprayed and unsprayed plots of apple trees and established in populations of apple leaf midge, Dasineura mali, giving increasing levels of parasitism. The same approach needs to be investigated for blackcurrant leaf midge. Natural enemies of the currant sowthistle aphid in blackcurrant crops have not been investigated previously. Such an investigation is an important first step to developing Integrated Pest Management approaches.
In this paper we briefly summarise the results of recent research to develop a forecasting model to better time applications of acaricides against the blackcurrant gall mite and progress to date with a three year research project, started in April 2000, to develop IPM approaches for blackcurrants.

**Forecasting model for gall mite emergence**

The emergence of the blackcurrant gall mite from galls on the early flowering blackcurrant cultivar Ben Lomond and the late flowering cultivar Ben Tirran was monitored closely in 1995-1999 using miniature sticky traps. First, 5% and 50% emergences varied from Julian day 74-112, 84-121 and 101-129 respectively in the different years (Table 1) but were virtually identical on the two varieties despite a 7-21 day difference in their flowering times. Predictions were obtained by temperature sums accumulated above a threshold of 4 ºC from Julian day 46 (15 February). The average accumulated temperatures for first, 5% and 50% emergences were 122, 199 and 316 degree days which gave mean errors in the predictions of 3.1, 1.3 and 7.2 days respectively.

<table>
<thead>
<tr>
<th>Year</th>
<th>First emergence</th>
<th>Observed day of</th>
<th>Predicted day of</th>
<th>5% emergence</th>
<th>Observed day of</th>
<th>Predicted day of</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Ben Lomond</td>
<td>Ben Tirran</td>
<td>Ben Lomond</td>
<td>Ben Tirran</td>
<td>Ben Lomond</td>
<td>Ben Tirran</td>
</tr>
<tr>
<td>1995</td>
<td>87</td>
<td>85</td>
<td>100</td>
<td>97</td>
<td>104</td>
<td>97</td>
</tr>
<tr>
<td>1996</td>
<td>106</td>
<td>86</td>
<td>115</td>
<td>97</td>
<td>106</td>
<td>97</td>
</tr>
<tr>
<td>1997</td>
<td>76</td>
<td>73</td>
<td>84</td>
<td>86</td>
<td>85</td>
<td>87</td>
</tr>
<tr>
<td>1998</td>
<td>112</td>
<td>6</td>
<td>121</td>
<td>89</td>
<td>76</td>
<td>92</td>
</tr>
<tr>
<td>1999</td>
<td>74</td>
<td>80</td>
<td>92</td>
<td>92</td>
<td>80</td>
<td>92</td>
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</table>

There was great day to day variability in the mean number of mites that emerged during the emergence period. Numbers emerging were suppressed on days when there was rainfall. There was a positive correlation between the number of mites emerging and mean or maximum daily temperature. The emergence of mites had a strong diurnal rhythm, with virtually no mites emerging between 23:00 hrs after dusk and 09:30 hrs, 4-5 hours after dawn the following morning. A laboratory experiment showed that the diurnal rhythm was controlled by both light and temperature. In 1999, galls contained 1400-2800 motile mites and 4500-6100 eggs throughout March and April when the internal tissue of the galls was green and succulent. In May, the internal tissue of the galls became progressively dry and chlorotic and numbers of eggs declined to <100 per gall. Though numbers of motile mites remained large, most were dead by the end of the month when the migration had more or less ceased. This work has been published in full by Cross and Ridout (2001).
The model is now starting to be used by UK blackcurrant growers for timing the application of sprays. A look up table giving day-degree percentage amounts for daily maximum and minimum air temperatures ranging from -4 to 30 °C has been released. Growers accumulate the percentage amounts from the 15 February. When the accumulated sum reaches 100%, first emergence is expected. Whether or nor actual emergence has started can be checked and the first acaricide spray applied which should be delayed if the weather is wet. When the accumulated sum reaches 160% (5% emergence) the emergence is well underway and it is important to ensure that an acaricide spray has recently been applied. When the sum reaches 250%, the emergence is at its peak. Acaricidal protection is critical and a further spray should be applied promptly. Using this approach should improve the standard of gall mite control and result in reductions in pesticide use, but whether or not these benefits accrue has yet to be demonstrated.

New research into IPM

A new 3-year research project was started on 1 April 2000 with the overall aim to develop effective Integrated Pest Management (IPM) approaches for mites, blackcurrant leaf midge and aphids on blackcurrant. The work has four component objectives:

1. To determine whether host plant resistance to gall mite (in cv Ben Hope) or reversion virus disease (in cv Ben Gairn) combined with two early season sprays of sulphur (at the start of gall mite migration) can prevent gall mite and/or reversion virus infection under conditions of severe pest pressure.

2. To determine the effects of such approaches on the natural enemies of other important pests. To determine the species compositions of the predatory mite fauna and how predatory and pest mite populations are affected by the IPM strategies for gall mite control.

3. To determine whether the parasitoid Platygastr demades can be exploited as a natural enemy of blackcurrant leaf midge (Dasineura tetensi) and whether it is adversely affected by the IPM strategies for gall mite control or a pre-blossom spray of chlorpyrifos or pirimicarb.

4. To characterise the natural enemy complex of the currant sowthistle aphid (Hyperomyzus lactucae) and to quantify levels of natural enemy attack in an IPM programme.

Methods

An experimental blackcurrant plantation was established at HRI-East Malling in autumn 1999. It consists of a 5 x 5 Latin square of 25 plots each of 36 blackcurrant bushes. Each plot contains three varieties in a split plot design, viz. Ben Hope (gall mite resistant), Ben Gairn (reversion virus resistant) and Ben Alder (susceptible). Five different insecticide/acaricide programmes are being applied as treatments:

1. 2 sprays of sulphur at the start of gall mite migration to control gall mite
2. 2 early sprays of sulphur + chlorpyrifos pre-flower to control to control gall mite and a wide range of insect pests
3. 2 early sprays of sulphur + pirimicarb pre-flower to control gall mite and aphids
4. three sprays of fenpropathrin at the standard timings for gall mite control to control all pests
5. untreated control.

As the migration of the blackcurrant gall mite commenced in late March 2000, a shoot bearing six blackcurrant gall mite galls was inserted into the soil in the centre of each row of each variety of each plot to act as a source of infestation. Two adjacent experimental
blackcurrant plantations, which are heavily infested with the gall mite, were also present (to the north and the northeast) ensuring the experimental plantation was exposed to severe infection pressure. The plantation was assessed for reversion virus infection just before flowering when the symptoms of the virus are most clearly visible. The number of galls which developed on each variety on each plot was counted in the dormant period at the end of the first year. The same assessments are to be done each year.

A sample of 25 expanded leaves was taken from each variety in each plot in July and August. The predatory mite species present were identified to species and the number of each species and the number of spider mites counted.

Only three leaf galls caused by blackcurrant leaf midge occurred in 2000 in the experimental plantation, 2 on bushes of Ben Alder sprayed with sulphur, only one on a Ben Gairn bush sprayed with chlorpyrifos. Populations were too low to study parasitism on the experimental plantation. However, apple leaf galls containing parasitised apple leaf midge larvae were introduced into every plot in summer. A heavy infestation occurred on a nearby old established plantation of Ben Lomond and Ben Tirran. Several thousand larvae were collected in June, July and August and were reared through to the adult stage to determine whether parasitoids were present.

Populations of aphids that developed in spring 2000 were very small and the predominant species was the permanent currant aphid (Aphis schneideri), which developed in July and August. Only very small numbers of colonies of currant sowthistle aphid developed. The number and size of colonies of each aphid species on each bush on each plot were assessed in June, July and August. The numbers of each species of predatory insect associated with the colonies were also assessed on each occasion. This was done by beat sampling and by inspecting the colonies directly for predators, parasitoids and pathogens.

**Results and discussion**

No reversion virus infection was found in 2000 or 2001. The number of black currant gall mite galls which had developed by the end of the first season (Table 2) were small but some important trends were apparent. The cultivars Ben Gairn and Ben Hope are both comparatively resistant to gall mite compared to the susceptible cultivar Ben Alder. The Ben Hope is categorised as gall mite resistant and appears, so far, to be fully resistant but the Ben Gairn is not. The reduced numbers of galls for all the sulphur treatments suggests that the application of sulphur is partially effective in controlling the gall mite. The original intention was to apply the first spray of sulphur at the start of the gall mite migration and the second at the peak. In the event, this was not done because of fears of phytotoxicity and taint caused by sulphur if applied during flowering. For this reason, the two sprays were applied before flowering at the standard times used by growers, viz. at bud break and at the first grape visible growth stage. This lead to less than optimal control of the mite as the sulphur did not give control throughout the migration period. This work indicates that later application of sulphur will be necessary if sulphur is to be relied on for control of the mite. Detailed investigation of possible phytotoxicity and taint from sulphur is needed. First years results of this work indicate that the standard programme of three sprays of fenpropathrin have very limited, if any, effect.

The distribution of galls on the plots was also interesting. Most galls occurred on the north and northeast sides of the experimental plot. These are the edges closest to older, established and heavily gall mite infested blackcurrant plots. It appears that the wind borne dispersal of mites into the plantation from these older plots was more important than that from the shoots bearing galls placed in the plots.
Table 2. Total number of blackcurrant gall mite galls per 60 bushes present in the dormant period after the first year

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Ben Alder</th>
<th>Ben Gairn</th>
<th>Ben Hope</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 sulphur</td>
<td>13</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>2 sulphur + chlorpyrifos</td>
<td>12</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2 sulphur + pirimicarb</td>
<td>14</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>3 fenpropathrin</td>
<td>30</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>untreated control</td>
<td>26</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Further results are needed before it can be concluded whether or not the combined use of gall mite or reversion virus resistance with sprays of sulphur will form an adequate Integrated Pest Management approach to gall mite and reversion virus control.

Numbers of predatory and spider mites present when samples were taken in June and July 2000 were very small. In August, two-spotted spider mite was present in small numbers on Ben Gairn with the greatest populations on the untreated control though differences were not statistically significant (Table 3). Intermediate populations were present on Ben Hope and populations on Ben Alder were very small. Small numbers of predatory phytoseiid mites were present throughout the plantation in August. There were no obvious treatment or cultivar effects though greatest numbers occurred on Ben Hope. The predominant species was the orchard predatory mite *Typhlodromus pyri* though about a quarter of the population comprised *Neoseiulus californicus* plus the odd individual of *Neoseiulus finlandicus*. These results suggest that predatory phytoseiid mites are potentially important natural enemies of spider mites on blackcurrant. They suggest that Ben Gairn and to a lesser extent Ben Hope are susceptible to two-spotted spider mite compared with Ben Alder. However, it is too early to conclude how effective they will be in the longer term and how they might be affected by cultivar and sprays of sulphur, chlorpyrifos, pirimicarb or fenpropathrin.

Only three leaf galls caused by blackcurrant leaf midge occurred in 2000 in the experimental plantation, 2 on bushes of Ben Alder sprayed with sulphur only one on a Ben Gairn bush sprayed with chlorpyrifos. No leaf midge was recorded in the experimental plantation in 2001, following a very wet winter. Populations were too low to study parasitism on the experimental plantation. However, apple leaf galls containing apple leaf midge larvae parasitised by *Platygaster demades* were introduced into every plot in summer 2001. A heavy infestation of the midge occurred on a nearby old established plantation of Ben Lomond and Ben Tirran in 2001. Several thousand larvae were collected in June, July and August and were reared through to the adult stage to determine whether parasitoids were present. The parasitoid *Platygaster demades* was found in about 1% of larvae. This confirms that the parasitoid does use blackcurrant leaf midge as a host but the levels of parasitism will need to be studied over several seasons to determine whether the parasitoid can be exploited as an effective natural enemy. Unfortunately, levels of leaf midge in the nearby old established plantation were near zero in 2001.

Populations of aphids that developed in spring 2000 in the experimental plantation were very small and the predominant species was the permanent currant aphid (*Aphis schneideri*). Only a few colonies of the currant sowthistle aphid (*Hyperomyzus lactucae*) developed. Beat sampling and inspection of the permanent currant aphid colonies in August 2000 showed that predatory flower bugs (anthocorids, mainly *Anthocoris nemorum*) followed by spiders were the most abundant predators (Table 4).
Table 3. Number of predatory phytoseiid mites and number of two-spotted spider mite, *Tetranychus urticae*, recorded per 125 leaves in August 2000

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Ben Alder</th>
<th>Ben Gairn</th>
<th>Ben Hope</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 sulphur</td>
<td>3</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>2 sulphur + chlorpyrifos</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2 sulphur + pirimicarb</td>
<td>0</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>3 fenpropathrin</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>untreated control</td>
<td>3</td>
<td>2</td>
<td>7</td>
</tr>
</tbody>
</table>

Number of two-spotted spider mite

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2 sulphur</th>
<th>2 sulphur + chlorpyrifos</th>
<th>2 sulphur + pirimicarb</th>
<th>3 fenpropathrin</th>
<th>untreated control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>22</td>
<td>17</td>
<td>277</td>
<td>98</td>
</tr>
<tr>
<td>2 sulphur + chlorpyrifos</td>
<td>5</td>
<td>26</td>
<td>15</td>
<td>98</td>
<td></td>
</tr>
<tr>
<td>2 sulphur + pirimicarb</td>
<td>1</td>
<td>36</td>
<td>10</td>
<td>116</td>
<td></td>
</tr>
<tr>
<td>3 fenpropathrin</td>
<td>1</td>
<td>34</td>
<td>9</td>
<td>132</td>
<td></td>
</tr>
<tr>
<td>untreated control</td>
<td>1</td>
<td>64</td>
<td>7</td>
<td>482</td>
<td></td>
</tr>
</tbody>
</table>

However, the predators were not able to eliminate the aphid colonies of permanent currant aphid in 2000 though it is likely that the size of the colonies was reduced. Numbers of predatory flower bugs were greatest on the untreated controls. However, aphid numbers were correspondingly lower on the insecticide treated plots.

In 2001, much greater populations of aphids occurred, mainly of the blackcurrant aphid, *Cryptomyzus galeopsidis*, and the currant sowthistle aphid (Table 5).

Table 4. Numbers of predators and permanent currant aphid (*Aphis schneideri*) recorded in 2000

<table>
<thead>
<tr>
<th>Treatment</th>
<th>ladybirds</th>
<th>anthocorids</th>
<th>spiders</th>
<th>aphids</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 sulphur</td>
<td>0</td>
<td>22</td>
<td>17</td>
<td>277</td>
</tr>
<tr>
<td>2 sulphur + chlorpyrifos</td>
<td>5</td>
<td>26</td>
<td>15</td>
<td>98</td>
</tr>
<tr>
<td>2 sulphur + pirimicarb</td>
<td>1</td>
<td>36</td>
<td>10</td>
<td>116</td>
</tr>
<tr>
<td>3 fenpropathrin</td>
<td>1</td>
<td>34</td>
<td>9</td>
<td>132</td>
</tr>
<tr>
<td>untreated control</td>
<td>1</td>
<td>64</td>
<td>7</td>
<td>482</td>
</tr>
</tbody>
</table>

Table 5. Mean number of aphid colonies per bush on 15-22 May 2001

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Ben Alder</th>
<th>Ben Gairn</th>
<th>Ben Hope</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blackcurrant aphid, <em>Cryptomyzus ribis</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 sulphur</td>
<td>1.6</td>
<td>7.1</td>
<td>3.3</td>
<td>4.0</td>
</tr>
<tr>
<td>2 sulphur + chlorpyrifos</td>
<td>0</td>
<td>0.1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2 sulphur + pirimicarb</td>
<td>0.1</td>
<td>0.5</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>3 fenpropathrin</td>
<td>0.6</td>
<td>3.1</td>
<td>1.9</td>
<td>1.9</td>
</tr>
<tr>
<td>untreated control</td>
<td>2.0</td>
<td>14.7</td>
<td>7.4</td>
<td>8.0</td>
</tr>
<tr>
<td>Currant sowthistle aphid, <em>Hyperomyzus lactucae</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 sulphur</td>
<td>2.6</td>
<td>1.6</td>
<td>0</td>
<td>1.4</td>
</tr>
<tr>
<td>2 sulphur + chlorpyrifos</td>
<td>0</td>
<td>0.3</td>
<td>0</td>
<td>0.1</td>
</tr>
<tr>
<td>2 sulphur + pirimicarb</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3 fenpropathrin</td>
<td>0.8</td>
<td>0.5</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>untreated control</td>
<td>0</td>
<td>2.3</td>
<td>0</td>
<td>0.8</td>
</tr>
</tbody>
</table>
Aphid numbers were greatest on the untreated controls followed by the 2 sprays of sulphur only treatment. Numbers on the fenpropathrin treated plots were greater than those on the chlorpyrifos or pirimicarb treated plots indicating that fenpropathrin is insufficiently effective against aphids. Numbers of blackcurrant aphid were greatest on Ben Gairn, followed by Ben Hope, with the lowest numbers on Ben Alder. Ladybirds were the predominant predators, greatest populations being associated with the greatest aphid numbers. The high numbers of ladybirds on these plots completely eliminated the aphids by 11 June 2001 although numbers of aphids were greatest initially. The predominant ladybird species were *Adalia bipunctata* and *Coccinella septempunctata* and *Psyllobora vigintiduopunctata*. The fenpropathrin treatment was harmful to ladybirds and only partially effective against aphids. The aphid colonies persisted longest on the fenpropathrin treated plots.

This initial information suggests that the aphid predator complex changes from year to year and according to the aphid host species present. Ladybirds and predatory flower bugs appear to be the most important natural enemy groups but further years of data are needed.

Acknowledgements

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References


Integrated crop management in strawberries in Ireland: Description, progress and future plans

T. Lola-Luz\textsuperscript{1,3}, F. MacNaidhe\textsuperscript{1}, R. Dune\textsuperscript{2}, P. Fitters\textsuperscript{3}, C. Griffin\textsuperscript{3}, M. Downes\textsuperscript{3}

\textsuperscript{1} Teagasc Soft Fruit Research Station, Clonroche, Ireland, \textsuperscript{2} Teagasc, Kinsealy, Ireland, \textsuperscript{3} NUI Maynooth, Ireland

Abstract: The main strawberry production in Ireland occurs in the Southeast of the country with Elsanta and Cambridge Favourite as the main cultivars. High levels of chemicals are applied to control pests including aphids, two-spotted spider mite, tarsenemid mites and the black vine weevil, which is the most serious pest. Failure to control these pests can result in low fruit quality, reduced yields and plant death caused by black vine weevil larvae. Recent withdrawal of chemicals, development of resistance, and environmental concerns, have lead to the search for alternative methods of control.

Key words: Black vine weevil, \textit{Botrytis}, 60-day system, plastic mulch

Introduction

The main strawberry production in Ireland occurs in the southeast of the country, with Elsanta and Cambridge Favourite as the main cultivars. In order to assure high fruit quality and production, most growers rely on chemicals. However, pesticides resistance has created the need for alternative ways of control. Integrated crop management aims to maintain pests and diseases below damaging levels. This is usually achieved by combined use of cultural, biological and chemical control methods. Strawberries are produced either indoors (60-day cropping or spring forced double-cropping) or outdoors (on bare drills or under black polythene mulch). Plants are subject to attack by many pests and diseases, such as the black vine weevil (\textit{Otiorhynchus sulcatus}), \textit{Botrytis} fruit rot and \textit{Phytophthora cactorum}. These pests and diseases consistently cause problems to growers each year, while other pests and diseases may occur occasionally. Our work aims to: a) provide two crop production systems with reduced pesticide dependence and b) provide frameworks of model systems that can be implemented now and be improved by experience. Here we describe our initial recommendations, our first results and our future plans to control the most important pest of strawberries: the black vine weevil.

Materials and methods

\textit{Experimental Systems}

A. 60-day system (Indoor): In this system, cv Elsanta is planted at the end of June. These yield a small crop in August to mid November and the main crop is April - May of the next year.

B. Black polythene mulch (Outdoor): Straw mulch is used to suppress weeds between the 1 m wide polythene strips. Planted in February on a 2-year rotation.
Table 1. Pests and Diseases of the two systems and proposed biocontrol agents to be used:

<table>
<thead>
<tr>
<th>Pests/ Diseases</th>
<th>Biocontrol agent</th>
<th>Indoors</th>
<th>Outdoors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black vine weevil</td>
<td><em>Heterorhabditis megidis</em></td>
<td>¥</td>
<td>¥</td>
</tr>
<tr>
<td>Two-spotted spider mite</td>
<td><em>Phytoseiulus persimilis</em></td>
<td>¥</td>
<td>¥</td>
</tr>
<tr>
<td>Tarsonemid mites</td>
<td><em>Amblyseius cucumeris</em></td>
<td>¥</td>
<td>¥</td>
</tr>
<tr>
<td>Aphids</td>
<td><em>Aphidius colemani</em></td>
<td>¥</td>
<td>Coccinellidae</td>
</tr>
<tr>
<td>Tortrix moths</td>
<td><em>Bacillus thurigiensis</em></td>
<td>¥</td>
<td>¥</td>
</tr>
<tr>
<td>Botrytis</td>
<td><em>Trichoderma sp</em></td>
<td>¥</td>
<td>¥</td>
</tr>
<tr>
<td>Phytophthora</td>
<td><em>Glomus sp.</em></td>
<td>¥</td>
<td>¥</td>
</tr>
<tr>
<td>Powdery Mildew</td>
<td><em>Ampelomyces quisqualis</em></td>
<td>¥</td>
<td></td>
</tr>
</tbody>
</table>

**Effectiveness of Entomopathogenic nematodes against black vine weevil in plastic modules outdoors**

The experiment was a randomised block design with three treatments, *Heterorhabditis megidis*, *Heterorhabditis downesi* and control. Ten days after application 9 blocks were harvested and the number of alive and dead insects was recorded. Data was log10 transformed and analysed by ANOVA.

![Figure 1. Effectiveness of entomopathogenic nematodes in strawberries grown in plastic modules outdoors.](image)

Results and discussion

Our trial showed that *H. megidis* achieved better control of the black vine weevil than the Irish strain, *H. downesi*. There were highly significant difference between treatments, with *H. megidis* causing higher mortality to black vine weevil larvae. These nematodes significantly
reduced the target pest population thus offering a viable alternative for biological control of the black vine weevil. Similar results have been demonstrated by other authors (Kaya 1985, Kaya, 1990, Georgis et al., 1991).

**Future Plans**

The study will evaluate:
- The effectiveness of entomopathogenic nematodes against the black vine weevil
- Study the biology of the weevil in Co. Wexford, Ireland
- Provide frameworks of model systems that can be implemented now and improved by experience

**Acknowledgements**

This project is supported by Teagasc, the Irish agricultural research organisation, through a Walsh Fellowship.

**References**


Raspberry pests in Serbia

Slobodan Milenkovic, Milojub Stanisavljevic
Agricultural Institute ‘Serbia’; Fruit and Grape Research Centre, 32000 Cacak, Yugoslavia

Abstract: Raspberry is a major small fruit crop in Serbia, covering about 14 000 ha. The surface of most plantings ranges from 0.05 to 0.25 ha, the cultivation of which engages an entire family. In terms of raspberry pest control, two up to four sprayings are applied on average. The major raspberry pests are as follows: small raspberry aphid (Aphis idaei), large raspberry aphid (Amphorophora idaei), strawberry blossom weevil (Anthonomus rubi), raspberry mite (Phyllocoptes gracilis), and two-spotted spider mite (Tetranychus urticae) (in droughty growing seasons). The damage caused by Lampronia (Incurvaria) rubiella, Lasioptera rubi, Melolontha melolontha, Tropinota hirta, Oxythirea funesta, and Oecanthus pellucens were also recorded in certain years. Up to 1999, organophosphates predominated among the insecticides used, and after that, pyrethroids have gradually been introduced. The onset of flowering is the deadline for the application of insecticides, whereas treatments are conducted even after harvest in the plantings attacked by raspberry mite and two-spotted spider mite.

Key words: raspberry, pests, control, insecticides, Serbia

Introduction

In terms of production scope and export, raspberry ranks first within small fruits in Yugoslavia with about 95% of production concentrated in central Serbia. The Government of Montenegro plans to invest in the establishment of 50-100 ha of raspberry plantings in autumn 2001. Over last 10 years, the production in Yugoslavia ranged from 41-64 000 t, becoming, thus, one of the leading producers worldwide (Stanisavljevic et al., 1998).

Climatic factors, fluctuation in prices, sanctions, coupled with diseases and pests appearance, are the key reasons for the aforementioned variation in the production scope. As compared to other countries with intensive production, the level of the control methods application has been low in Serbia, thus 2 up to 4 sprayings have commonly been applied in the plantings. Even 16% of producers within Dragacevo region (one of the largest production areas in Serbia) do not apply pesticides for raspberry pest control (Milenkovic et al., 2000). Total area under raspberry in Yugoslavia accounts for about 14 000 ha, the surface of most plantings ranging from 0.05 to 0.25 ha.

The major pests in terms of spread and damage in raspberry plantings in Serbia are as follows: small raspberry aphid (Aphis idaei), large raspberry aphid (Amphorophora idaei), strawberry blossom weevil (Anthonomus rubi), raspberry mite (Phyllocoptes gracilis), two-spotted spider mite (Tetranychus urticae) (in droughty growing seasons). The injuries caused by Lampronia (Incurvaria) rubiella, Lasioptera rubi, Melolontha melolontha, Tropinota hirta, Oxythirea funesta, and Oecanthus pellucens were also registered in certain years. Up to 1999, organophosphates predominated among the insecticides used. Two common i.e. sprayings, at the phase of leafing and prior to flower opening, were applied. The application of insecticides after harvest was rare. Over last three years, more intensive cooperation between private companies and institutes concerning the introduction of integrated control programmes has been made.
Material and methods

Over 1999-2001, raspberry pests were monitored in 470 plantings in the major production regions: Dragacevo, Arilje, Kopaonik, and Valjevo. The samples were collected in 15-day intervals during growing season (March-September). Yellow traps were used for assessing the number of leaf aphids; light traps were used for Melolontha melolontha and Rebell bianco traps for raspberry beetle and Tropinota hirta. Since Phyllocoptes gracilis has been noticed in all the regions, control in mother plantings, in order to prevent the major way of spreading via planting material, was conducted. The spectrum of the insecticides used, number of treatments, deadlines for application and control efficacy were monitored in the aforementioned localities.

Results and discussion

The presence of small raspberry aphid (Aphis idaei) (Table 1) was recorded in most raspberry plantings (from 34% to 86% varying with year), which is also confirmed by previous studies (Zivanovic, 1974). It surely resulted from non-application of insecticides after harvest in most plantings up to 1999. Over the last 10 years, dimethoate was commonly used for aphid control, and the introduction of an integrated control programme gradually led to pyrethroid introduction (deltamethrin, lambda cyhalothrin) and carbamates (pirimicarb).

Significant numbers of large raspberry aphid Amphorophora idaei were recorded only in the plantings within hilly regions. Sprayings aiming at the control of leaf aphid colonization are carried out in mother plantings at 15-day intervals.

Overwintering females of raspberry eriophyd mite Phyllocoptes gracilis emerge on leaves in late April and early May. They were observed on leaves till mid-November. The population number ranges from 10 per leaf up to even 20 mobile forms/cm². Mites cause a special problem, since the small surface of the plantings and distance aggravate detection and determination of the time for the acaricide application. Two maximal numbers exist (in late July and early August – on two-year shoots, and in October – on one-year shoots). Since dimethoate had for a long time been applied within the insecticides, and acaricides have been rarely used, it may be assumed that, apart from uncontrolled spreading via planting material from commercial plantings, the aforementioned facts led to the spread of raspberry mite. Intensive control methods from 1999, primarily in mother plantings, have reduced the pest number. Fenazaquin and endosulphan proved to be highly effective.

During the 1980s the common cockchafer Melolontha melolontha was the major raspberry pest on the slopes of the western Serbian mountains. In early May 2001, the year of swarming, a high number of imagos (up to 6 per raspberry plant) was observed. Thus, mechanical collection and destruction were carried out. Soil insecticides have been applied at the establishment of new plantings. In addition, Tropinota hirta and Oxythirea funesta appeared in all the production areas in 2001. Since the application of insecticides is forbidden during flowering time, white traps and mechanical collection were applied as a control method. The mentioned procedure has effectively been conducted in Serbia, since sufficient manpower exists within small plantings.

Contrary to most part of Europe, in which a highly important pest is raspberry beetle (Byturus tomentosus) (Gordon et al., 1999), its significance is less in Serbia. Only small numbers were registered on Rebell bianco traps in hilly regions, in which the level of insecticide application is low. Strawberry blossom weevil regularly emerges in high numbers at plain and hilly terrains within the Arilje production area. It is effectively controlled by the application of fenthion, fosfamidon, cipermethrin + monocrotophos.
Table 1. Raspberry pests and their significance in Serbia

<table>
<thead>
<tr>
<th>Latin name</th>
<th>Common name</th>
<th>Distribution</th>
<th>Harmfulness and importance</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Aphis idaei</em></td>
<td>Small raspberry aphid</td>
<td>Widespread</td>
<td>++++</td>
</tr>
<tr>
<td><em>Amphorophora idaei</em></td>
<td>Large raspberry aphid</td>
<td>Localised (mountainous regions)</td>
<td>+++</td>
</tr>
<tr>
<td><em>Anthonomus rubi</em></td>
<td>Strawberry blossom weevil</td>
<td>Widespread (Western Serbia)</td>
<td>++++</td>
</tr>
<tr>
<td><em>Lasioptera rubi</em></td>
<td>Raspberry midge</td>
<td>Widespread</td>
<td>++</td>
</tr>
<tr>
<td><em>Lampronia rubiella</em></td>
<td>Raspberry moth</td>
<td>Localised</td>
<td>+</td>
</tr>
<tr>
<td><em>Melolontha melolontha</em></td>
<td>common cockchafer</td>
<td>Localised (certain plantings at the altitude of 400-700 m)</td>
<td>+++ (a)</td>
</tr>
<tr>
<td><em>Tropinota hirta</em> and <em>Oxythirea funesta</em></td>
<td>hairy beetles</td>
<td>Widespread</td>
<td>++ (b)</td>
</tr>
<tr>
<td><em>Phyllocoptes gracilis</em></td>
<td>Raspberry mite</td>
<td>Widespread</td>
<td>+++</td>
</tr>
<tr>
<td><em>Tetranychus urticae</em></td>
<td>Two-spotted spider mite</td>
<td>Widespread</td>
<td>++ (in drought and warm years)</td>
</tr>
<tr>
<td><em>Oecanthus pellucens</em></td>
<td>Italian cricket</td>
<td>Localised</td>
<td>+</td>
</tr>
<tr>
<td><em>Byturus tomentosus</em></td>
<td>Raspberry beetle</td>
<td>Widespread (more numerous in hilly regions)</td>
<td>++</td>
</tr>
</tbody>
</table>

++++ = pest which causes great damage if not controlled
+++ = pest which causes damage if not controlled
++ = pest which causes damage in certain years
+ = pest which causes damage in individual plantings
a = upon years of swarming (three-year development cycle) great damage during 'eighties
   in May of 2001, a high number of imagos were recorded in raspberry plantings
b = the first half of May, 2001, 12% of flowers damaged.

Over the last three years, the number of major raspberry pests varied (Table 2.). During the drought of 2000, the greatest attack and damage of aphids, mites and blossom weevil were recorded. It is of importance that a severe attack of *Tropinota hirta* and *Oxythirea funesta* occurred only in 2001, when the damage on flowers induced by low temperature in other fruit crops was observed. It is assumed that this pest, lacking other hosts, passed on raspberry at full bloom. The number of two-spotted spider mite is high mostly at the second half of growing season, thus acaricides have been applied after harvest (August-September).
Table 2. Maximal population number/attack intensity of major raspberry pests in Serbia

<table>
<thead>
<tr>
<th>Pest</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Aphis idaei</em></td>
<td>5-15% canes attacked</td>
<td>30-75% canes attacked</td>
<td>10-20% canes attacked</td>
</tr>
<tr>
<td><em>Phyllocopites gracilis</em></td>
<td>10-20 mobile forms/cm²</td>
<td>up to 50 mobile forms/leaf</td>
<td>5-20 mobile forms/leaf</td>
</tr>
<tr>
<td><em>Tetranychus urticae</em></td>
<td>0.5% plantings attacked; 2-5 mobile forms/leaf</td>
<td>31% plantings attacked; up to 50 mobile forms/leaf</td>
<td>12% plantings attacked; up to 5 mobile forms/leaf</td>
</tr>
<tr>
<td><em>Anthonomus rubi</em></td>
<td>5% plants attacked</td>
<td>12% plants attacked</td>
<td>7% plants attacked</td>
</tr>
<tr>
<td><em>Tropinota hirta</em></td>
<td>not recorded</td>
<td>0.5% plants attacked</td>
<td>12% plants attacked</td>
</tr>
</tbody>
</table>

Up to now, the mostly applied insecticide, dimethoate, has gradually been replaced by pyrethroids (deltamethrin, lambda cyhalothrin) (Table 3). Endosulphan will further be used owing to its efficacy in *Phyllocopites gracilis* control. However, its application has been limited to one spraying annually. Other acaricides are alternatively applied after harvest. In terms of raspberry control in Serbia, the last deadline for the application (which in 75% of the plantings studied were up to the beginning of flowering) is a positive pesticide trait.

Table 3. Spectrum of insecticides and acaracides applied (active ingredients) for raspberry control in Serbia

<table>
<thead>
<tr>
<th>In the plantings with conventional control programmes</th>
<th>In plantings with integrated control programmes</th>
</tr>
</thead>
<tbody>
<tr>
<td>dimethoate&lt;sup&gt;a&lt;/sup&gt;</td>
<td>deltamethrin</td>
</tr>
<tr>
<td>endosulphan&lt;sup&gt;b&lt;/sup&gt;</td>
<td>lambda cyhalothrin</td>
</tr>
<tr>
<td>methidathion</td>
<td>phosalon</td>
</tr>
<tr>
<td>fenthion&lt;sup&gt;c&lt;/sup&gt;</td>
<td>pirimicarb</td>
</tr>
<tr>
<td>cipermethrin</td>
<td>fenazaquin</td>
</tr>
<tr>
<td>brompropylate&lt;sup&gt;c&lt;/sup&gt;</td>
<td>mineral oil</td>
</tr>
<tr>
<td>propargite</td>
<td>mineral oil + parathion or methidathion</td>
</tr>
</tbody>
</table>

<sup>a</sup> = applied in 75% of the plantings in which insecticides are used  
<sup>b</sup> = applied in 30% of the plantings in which insecticides are used  
<sup>c</sup> = up to 1998., used for controlling *Phyllocopites gracilis*, out-of-use at present  
<sup>x</sup> = applied in the regions with severe blossom weevil attack (Arilje area)

In terms of maximal residue levels, strict criteria exist in Yugoslavia. As regards their value, they are in compliance with the regulations in Europe (Table 4.).
Table 4. Maximal residue levels (MRL) of the insecticides allowed for raspberry pests control in Yugoslavia

<table>
<thead>
<tr>
<th>Active ingredient</th>
<th>MRL (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>dimethoate</td>
<td>1</td>
</tr>
<tr>
<td>endosulphan</td>
<td>1</td>
</tr>
<tr>
<td>methidathion</td>
<td>0.02</td>
</tr>
<tr>
<td>cypermethrin</td>
<td>0.5</td>
</tr>
<tr>
<td>deltamethrin</td>
<td>0.1</td>
</tr>
<tr>
<td>lambda cyhalothrin</td>
<td>0.1</td>
</tr>
<tr>
<td>phosalone</td>
<td>1</td>
</tr>
<tr>
<td>pirimicarb</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Acknowledgements

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References

Changes of the dominance of arthropod pest species in Hungarian raspberry plantations

Mária Szántóné Veszelka, Mária Fajcsi
Plant Protection and Soil Conservation Service of Nograd County, Balassagyarmat, Hungary

Abstract: The Plant Protection Service of Nograd county has been carrying out arthropod pest monitoring and assessment of control technologies in raspberry since 1968. In 1997 a new programme was started aiming at evaluation of changes in the structure of arthropod populations and their importance in terms of damage caused. This evaluation will contribute to implementation of integrated pest control programmes. Ten representative sites have been selected throughout the raspberry-growing region. Occurrence of arthropod pests, their spread, density and damage caused to the plants have been recorded in four vegetative stages of the crop. The arthropods have also been identified by species.

According to the results currently in Hungary the following insects have been considered pests in raspberry (in descending range of their harmfulness): a Rose stem girdler (*Argilus aurichalceus*), Small Raspberry Aphid (*Aphis idaei*), Blackberry Stem Gall Midge (*Lasioptera rubi*), Bramble Shoot Moth (*Notocelia udmanniana*), Raspberry Beetle (*Byturus tomentosus*), Strawberry Blossom Weevil (*Anthonomus rubi*), Raspberry Moth (*Lampronia rubiella*) and Raspberry Cane Midge (*Resseliella theobaldi*). In comparison with previous decades the Raspberry Cane Midge has lost its dominating role. The Raspberry Beetle occurs occasionally, mostly as a component of insect fauna within the crop without causing damage. In contrary, several species, e.g. the Rose stem girdler, have become prevalent. In addition, during the last two years of surveys mites (*Tetranychus urticae* and *Phyllocoptes gracilis*) were observed to spread widely in raspberry plantations.

Key words: Arthropod pest monitoring, raspberry pests in Hungary, *Agrilus aurichalceus*, *Lasioptera rubi*, *Notocelia udmanniana*, *Byturus tomentosus*, *Anthonomus rubi*, *Lampronia rubiella*, *Resseliella theobaldi*, *Tetranychus urticae*, *Phyllocoptes gracilis*

Introduction

In Hungary, raspberries (*Rubus idaeus*) are valuable cane fruits grown on about 2,000 hectares. The commercial production concentrates to northern Hungary (Nograd and Heves counties), an ecologically highly favourable region for growing small fruits. 70% of the total acreage is located in these two counties.

After the years of the changing of political regime, most large-scale farms disappeared and raspberry is mostly grown in small family farms and private gardens. Though profitability of raspberry growing is uncertain because of the market conditions, this small fruit is, nevertheless, an important source of living and income for the growers. Pest management is a basic element of the production and is required to obtain marketable high quality fruits. Successful pest control is based on the knowledge of pest range and pest dynamics. The Plant Protection Service has been carrying out representative surveys on the places of production in order to assess the pest situation as well as to improve the pest management programmes by means of biological investigations and trials with plant protection products.

During these surveys, lasting and significant changes in the pest populations have been recorded which might modify the structure of arthropod populations. Data collection has been started to confirm the hypothesis.
Materials and methods

The monitoring data collected by the Plant Protection and Soil Conservation Service since 1968 were processed. In 1997 a new programme has started aiming at the evaluation and recording of changes in the structure of arthropods and their importance in terms of caused damages. Ten representative sites have been selected for monitoring during the growing season: the plants were of different age, varieties, production level, and cultivation. Occurrence of arthropod pests, their spread, density and damages to the plants were recorded during four growth stages of the plants.

To make comparison easier, the spread of the pest species was expressed by the infestation % of the area, while the population density and the extent of damages by the infestation % of the plants. For the evaluation of data, we determined the range of major pests, the severity of their damage and underlined the trends of developments necessary both for the pest management programmes and the research tasks. The population dynamics/pest species were recorded on graphs, then the changes in population were shown on a figure. The infestation % of the area and the pest density are jointly expressed in terms of infestation level on a scale where 1, 2 and 3 mean low, medium and high infestation.

Results

According to the results, it was found that seven pest species or groups of species play an important role in the management of raspberry: Rose stem girdler (*Agrilus aurichalceus* Redtenbacher), Blackberry stem gall midge (*Lasioptera rubi* Schrank), Bramble shoot moth (*Notocelia udmanniana* L.), Strawberry blossom weevil (*Anthonomus rubi* Herbst), Raspberry beetle (*Byturus tomentosus* De Geer), Raspberry cane midge (*Resseliella theobaldi* Barnes) and Raspberry moth (*Lampronia rubiella* L.).

![Figure 1. Population dynamics of Raspberry cane midge](image-url)
**Raspberry cane midge**

From the early 1970s, raspberry cane midge became an important pest with the upcoming of large fields in cooperative farms, then, later, it has become one of the most dangerous pests of economic importance. In addition to the low level of pest control at that time, the great increase of population was also supported by the wide use of varieties (“Malling Exploit”, “Promise”, “Nagymarosi”) with easily cracking canes. Severe damages caused by raspberry cane midge appeared together with high epidemic level of cane diseases (*Leptosphaeria*).

From the early 1990s, the size of the infested area and the infestation level have gradually decreased. In addition to the consecutive dry years, the important reduction in the population density may have been caused by the intensive use of pesticides and the gradual change of varieties (spread of the more tolerant tasty variety “Fertődi” with hard skin). From 1997, the pest has occurred constantly at low population density.

**Raspberry moth**

During the period under study, this pest regularly occurred. Its first establishment in raspberry was recorded in the mid-1960s. Between 1977 and 1983, the increase of population density caused 25-30% bud damage in certain fields. Since then it has appeared only in spots. From 1997, the raspberry moth has newly established in old abandoned plantations with insignificant infestation level.

![Figure 2. Population dynamic of Raspberry moth](image)

**Strawberry blossom weevil**

According to the available data, damage caused by strawberry blossom weevil was first recorded in raspberry plantations in 1971. Since that time, it has caused medium to heavy infestation, depending on the weather conditions as well as on the pest management level. In years with warm and dry May and June, severe bud injury was observed in raspberry plantations. During the last five years, bud damage has been insignificant but the infestation has been distributed, so we have to be prepared with pest management programmes.
Figure 3. Population dynamics of Strawberry blossom weevil

**Raspberry beetle**

During the period under study, the raspberry beetle appeared only occasionally, frequently as associated species to strawberry blossom weevil, in years where this latter occurred in high population density. Heavy infestations established only in spots, mostly in raspberry plantations in the vicinity of woodlands. During the early 1980s, it almost disappeared from the plantations, it could only be found at detection level as part of the fauna. No severe damages are observed. The reason for significant reduction of the pest density is not really known but it coincides in time with the general application of pyrethroid insecticides, therefore the relationship may be established.

**Bramble shoot moth**

Regular but different levels of infestation by bramble shoot moth are observed in raspberry plantations. No major damage could, however, be observed even in case of the highest pest density. The occasional presence of the moth was spectacular on the sprouts. Based on data of the surveys made in the last 3 years, the species has been widely distributed with constant medium level infestation.
Blackberry stem gall midge
Blackberry stem gall midge is known as an insect of home gardens because it needs no chemical treatments in well-protected and maintained plantations. It has low infestation level but it appears regularly. The temporarily increase of population density is caused by the weather conditions favourable for the pest and the inappropriate sanitary level. The heavy infestation peak in 1981-1983 was the consequence of many abandoned plantations due to the dramatic decrease in the price of raspberry. The damage constantly increased between 1995 and 1999, but this trend stopped in 2000.
Between 1968 and 2000, attacks by rose stem girdler were observed in two periods. In 1968-1970, it had no general distribution, but caused, however, severe local damage. Later, probably because of intensive cultivation in large-scale farms, it was not observed in
Figure 8. Infestation level of pests
raspberry plantations until 1991. After its local appearance, it became distributed widely. From the mid-1990s, regular but different levels of infestation were observed even in well-maintained plantations. Its sources are in abandoned, not-pruned plots with high weed coverage.

During the last two years of surveys, raspberry leaf and bud mites (*Phyllocoptes gracilis*) have established in high number. The dry warm weather induced heavy infestations by the two-spotted spider mites (*Tetranychus urticae*). Great attacks were observed in 1999, and very important nation-wide increase of population density was recorded in 2000.

**Discussion**

Between 1968 and 2000 under study, significant changes took places in the dominance of pest populations attacking raspberry plantations. In the first years of the study period, raspberry cane midge and raspberry beetle had mainly to be controlled, but nowadays the population of these species has established at a low level. The role of bramble shoot moth and blackberry stem gall midge has greatly increased and these pests are constantly present. Though strawberry blossom weevil has had low infestation levels for recent years, its wide distribution may cause, under favourable conditions, damage of great importance.

The rose stem girdler has become the major pest of raspberry plantations over a decade.

The change in the dominance among the above species is understood as a complex phenomenon. Several abiotic, biotic and human factors may have contributed to the reduction of certain pests, on the one hand, as well as to the population increase of others, on the other. The most important are: change in the climate, change in the varieties used, establishment of smaller plantations, difference in production levels, intensity and reliability of plant protection as well as difference in the professional and technical knowledge of the growers and the presence of natural regulating elements.

The changes in the pest dominance are a new challenge for working out more reliable pest management programmes. Our survey may contribute to the development of the model for integrated pest management in raspberry.

**References**


Pest control by means of natural enemies in raspberry and red currants under plastic tunnel

D. Bylemans¹, C. Janssen¹, G. Latet², P. Meesters², G. Peusens¹, F. Pitsioudis², G. Wagelmans¹
¹ Research Station for Fruit Growing, Royal Research Station of Gorsem, De Brede Akker 13, B-3800 Sint-Truiden, Belgium
² Research Station for Fruit Growing, Experimental Garden for Small Fruits, Sint-Truidersteenweg 321, B-3700 Tongeren, Belgium

Abstract: During 3 successive years trials were executed in Belgium to determine the effectiveness of phytoseiid mites (Neoseiulus californicus, Phytoseiulus persimilis and Typhlodromus pyri) and the predatory midge Feltiella acarisuga for the control of Tetranychus urticae. In all cases, N. californicus was shown to be most effective to avoid damage of this mite pest in small fruits grown under plastic tunnel conditions. The maximum average number of T. urticae never exceeded 150 per 10 leaves and the prey/predator ratio was maximal 20. In raspberries, with the cultivar Autumn Bliss being extremely susceptible for T. urticae, F. acarisuga is an essential aid for long term control till the end of the season, especially if warm autumn conditions occur. P. persimilis might eventually be introduced in the two-spotted spider mites spots if the prey/predator ratio of 20 is exceeded for N. californicus. The number of spider mites in red currants is generally lower than in raspberry. Also here, N. californicus was able to control the pest. The control of western flower thrips, Frankliniella occidentalis, was successful by the releases or natural presence of Orius spp. Thrips number could be held lower in comparison to a tunnel treated with chemical insecticides.

Key words: Neoseiulus californicus, Feltiella acarisuga, phytoseiid, Orius, Tetranychus urticae, Frankliniella occidentalis, integrated pest control

Introduction

Belgian fruit growers have a high interest in practising IPM in cane fruits and currants. A full dependence on chemical compounds, which have to be registered against the target pests, is almost impossible. Due to the formation of resistance of major pests in small fruits (i.e. Tetranychus urticae against METI-acaricides) chemical control becomes difficult (Bylemans and Meurrens, 1997). For other pests, like Frankliniella occidentalis, no effective plant protection products are registered in these cultures since the registration of heptenophos and mevinphos had been withdrawn. Other advantages of biological control methods are the lack of chemical residue and the absence of operator exposure during the application of the compounds. Technical difficulties still occur but the represented trial results under semi-practical conditions indicate that practising IPM in small fruits is not unrealistic. To minimise financial costs and the number of technical failures, the success of several beneficials was compared, taking into consideration fundamental differences of their predatory behaviour (Peusens and Bylemans, 2000).
Figure 1: Evolution of the population of predatory mites *Neoseiulus californicus* (Part 1), *Typhlodromus pyri* (Part 2) and *Feltiella acarisuga* (Part 3) and the calculated prey/predator ratio in raspberry grown in a plastic tunnel.
Materials and methods

**Beneficials**

Beneficials, except *T. pyri*, were obtained from the regular commercialised strains of the company Biobest (Westerlo, Belgium). Two mobile stages of *N. californicus* or *P. persimilis* per metre row length and metre row height were released. These small amounts of beneficials were obtained by the measurement of the weight of divided samples (including the supporting material like vermiculite) after thoroughly but gently homogenising the beneficials inside the recipient by turning and shaking it.

**Assessment of *Tetranychus urticae* and phytoseiids**

Mites were counted by brushing 10 leaves above glass plates and counting the collected mobile stages under a binocular microscope (12-x magnification).

**Comparison of predators of *Tetranychus urticae* on raspberry**

A plastic tunnel (width 8 m, height 3.5 m) with 2 rows of raspberry (cv. Autumn Bliss) of 30 m long was divided in 4 parts. Part 1 and 2 were separated from part 3 and 4 by a plastic sheet. In part 1 and 2 the gall midge *Feltiella acarisuga* was released by placing an opened pot containing 250 pupae in the centre of this tunnel part. New pots with *F. acarisuga* were opened on 25 June, 7 July and 30 July. In part 1 and 3 *Neoseiulus californicus* was released at 2 mites per metre. Five releases of *N. californicus* were executed between May 20th and July 30th. On part 2 *Typhlodromus pyri*, was brought in. In part 4 no beneficials were released. *T. pyri* was obtained from shoots of approximately 1 m long, cut from apple trees. Three times, shoots with *T. pyri* were brought into the raspberry plants (9 May, 10 June and 3 August).

**Control of *T. urticae* by *N. californicus* in red currants**

Two consecutive releases of *N. californicus* were executed as described for raspberry.

**Control of *F. occidentalis* by Orijus laevigatus in raspberry.**

Two adults per m² tunnel of *O. laevigatus* were introduced twice with an interval of a week. They were released at two spots per row.

**Results**

**Comparison of beneficials for control of *T. urticae* on raspberry**

In a first trial, the success of *N. californicus*, *T. pyri* and *F. acarisuga* for the control of *T. urticae* in raspberry was compared in separated tunnel compartments (Fig. 1, part 1). In the compartment in which *N. californicus* was released, *T. urticae* was present from the end of June. When numbers of *T. urticae* reached a level of 7.5 per leaf, sufficient predatory mites were present to decrease the number of spider mites afterwards. Due to the warm climatological conditions, a second peak of spider mites occurred in early August, but again it was followed by an increase of the number of phytoseiids. The prey/predator ratio was maximal 15 in the beginning of the season but decreased strongly afterwards. In the compartment in which *T. pyri* was released, the maximum number of *T. urticae* was comparable with the number in the *N. californicus* compartment, but they remained present for a longer time (Fig. 1, part 2). The number of phytoseiids was lower than in the *N. californicus* plot. But like in the *N. californicus* plot, the prey/predator ratio never exceeded 15. Similar numbers of *T. urticae* were present in the plot in which only *F. acarisuga* was released, but a considerable number of *T. urticae* remained present much longer (Fig. 1, part 3). *F. acarisuga* was hardly found during the whole growing season. However, phytoseiids were detected in this compartment and the prey/predator ratio (with phytoseiids considered as
the predator) at its maximum was lower compared to the other plots. If a species determination of the present phytoseiids was executed for each plot, the dominance of *N. californicus* became clear (Fig. 2). Even in the *T. pyri* plot, 67% of the phytoseiids was *N. californicus* indicating its high speed of migration and its better beneficial capacity. In the *F. acarisuga* plot, more than 90% of the phytoseiids was *N. californicus*. In each plot a very small number of *P. persimilis*, which was not introduced, was present. They were observed to be present on the supporting material (dried bean leaves of the *F. acarisuga* pupae).

Figure 2: Percentage of each species after determination of predatory mites in raspberry grown under plastic tunnel after releases of *N. californicus* (left), *T. pyri* (middle) or *F. acarisuga* (right).

Figure 3: Evolution of the population of *Tetranychus urticae* and *Neoseiulus californicus* and the calculated prey/predator ratio in raspberry grown in a plastic tunnel.
In another experiment, the simultaneous release of *N. californicus* and *F. acarisuga* was tested for its success in mite control on raspberry. A slight increase of spider mite population could be observed resulting in a maximum number of 100 *T. urticae* per 10 leaves at the end of September (Fig. 3). In very early stages, the predatory mite *N. californicus* could be detected. Due to the increase of phytoseiids in October, the number of spider mites dropped fast. The prey/predator ratio was at the maximum 20. We could find maximal 8 *N. californicus* per 10 leaves. In this trial *F. acarisuga* could be detected by the presence of L2-L4 larval stages or pupae on the leaves (Fig. 4). However, the number of gall midges was low in comparison to the number of phytoseiids. In a third trial, the phytoseiids *N. californicus* and *P. persimilis* were compared (Fig. 5). The number of *T. urticae* was maximal 145 per 10 leaves. *N. californicus* could be detected much earlier in the season. *P. persimilis* was only observed if mite numbers were at their highest level. The increase of the population of *P. persimilis* was much faster than the one of *N. californicus*.

**Figure. 4: Evolution of the population of *Tetranychus urticae* and *Feltiella acarisuga* and the calculated prey/predator ratio in raspberry grown in a plastic tunnel.**

*Control of T. urticae by N. californicus in red currants*

Although the number of *T. urticae* was much lower on red currants (at the maximum 20 per 10 leaves) chemical treatments might be necessary in some cases. Our trial indicated the capacity for *N. californicus* for biological control of this pest on red currants (Fig. 6). The prey/predator ratio was 6.8 at the highest.
**Figure 5**: Evolution of the population of *Tetranychus urticae*, *Neoseiulus californicus* and *Phytoseiulus persimilis* in raspberries grown in a plastic tunnel.

**Figure 6**: Evolution of the population of *Tetranychus urticae* and *Neoseiulus californicus* and the calculated prey/predator ratio in red currants grown in a plastic tunnel.

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**Control of *F. occidentalis* by *O. laevigatus* in raspberry**

The development of the western flower thrips, *F. occidentalis*, was compared in a plot in which *O. laevigatus* was released and a plot with a repeated treatment of mevinphos (Fig. 7). Thrips numbers in the IPM plot were higher at the onset of the trial but the thrips population remained low (maximum number of 6 per 10 flowers) for the rest of the season. In the
chemically treated plot, the initial population of *F. occidentalis* was lower due to the chemical treatments, but afterwards up to 34 thrips per 10 flowers were monitored.

Figure 7: Evolution of the population of *Frankliniella occidentalis* and *Orius niger* on raspberry grown in a plastic tunnel compartment with respectively integrated and chemical pest management

**Discussion**

From 1998 till 2000 several trials were executed to control spider mites and thrips on raspberry and red currants grown under plastic tunnel. Good results were obtained by the release of the phytoseiid *Neoseiulus californicus*. These releases should take place before the first important infestations so that its population can build up before the population of *T. urticae* is too high. Especially for the cv. Autumn Bliss, a raspberry cultivar that is highly sensitive for this pest, additional consecutive releases of *F. acarisuga* are advised. This beneficial could not be found each year, but its presence was shown to be of importance in late summer in some of our experiments. Only in one case, the predatory mite *Phytoseiulus persimilis* was found in raspberry. Workers from neighbouring strawberry fields might spread this phytoseiid. Especially in cases of spots of *T. urticae*, local release of this predator is present. The negative influence of low relative humidity on the hatching of its eggs (Peusens and Bylemans, 2000) is probably of lesser importance in raspberry compared with strawberry due to a more humid microclimate in raspberry. *Typhlodromus pyri*, which is of extremely high value in orchards and vineyards and which was shown to be active on raspberry (Baillod et al., 1996), was less competitive in comparison with *N. californicus* in our conditions.

Although mite control was always successful in the described trials, the current season (2001) yielded an insufficient mite control by natural enemies (results not shown) for the raspberry cultivar Autumn Bliss. Especially, when a new planting is made, the first year is difficult to manage with biological control only. This experience might suggest that (part of) the beneficials overwinter and guarantee a better control in the next season.
Thrips were easily controlled by released (Fig. 7) or naturally present (results not shown) *Orius* spp. These predators might profit by the presence of lots of flowers during considerable periods in raspberry and blackberry. The effect of releases of *Amblyseius cucumeris* were not studied for thrips control in small fruits, but it might be interesting due to its effects on other noxious mite pests as *Acalitus essigi* in blackberry (own preliminary experience, results not shown).

The total cost of releases of beneficials (not taking into account labour cost of releases or monitoring) varied a lot depending on the choice of beneficial and the number of introductions. The minimal cost during all these years was 0.07 EURO/m² and the maximum cost was 0.89 euro/m².

Some problems still remain. Due to the lack of selective compounds that can be used if natural enemies fail to control pests, a higher (financial) risk is present for the grower. The authorisation of new selective plant protection compounds might be helpful to decrease this risk. The very specific small fruits aphids (*Sitobion fragariae, Amphorophora rubi,* *Amphorophora idaei,*.....) might cause important economical damage before biological control is possible. Often, parasitization by commercially available parasitic wasps as *Aphidius colemani, A. ervi* and *Aphelinus abdominalis* is poor. Aphid predators as *Harmonia axyridis, Chrysoperla carnea* and *Aphidoletes aphidimyza* only work well if bigger colonies of aphids are present. It is often not clear whether the eventual control is realised by naturally invading species or by the released beneficials.

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**References**


Greenhouse production of strawberries and blackberries in Norway – arthropod pests and biological control

Nina Trandem
Plant Protection Centre, Department of Entomology and Nematology, The Norwegian Crop Research Institute, Høgskoleveien 7, N-1432 Ås, Norway

Abstract: In recent years, a few Norwegian growers have started greenhouse berry production in order to sell freshmarket berries out of season. Few (strawberry) or no (blackberry) insecticides/acaricides are registered for use in greenhouse berries, and biocontrol is used where possible. I here sum up the experiences with arthropod pest control from two R&D projects involving four growers, including an experiment with the predatory mite *Neoseiulus californicus* in strawberry. Spider mite (*Tetranychus urticae*), strawberry mite (*Phytonemus pallidus*), several aphid species, thrips, and root weevils (*Otiorhynchus*) were kept at satisfactory low levels most of the time, while the following species were problematic because they could not be controlled by beneficials commercially available in Norway: honeysuckle whitefly (*Aleyrodes lonicerae*) in strawberry; permanent blackberry aphid (*Aphis ruborum*), rose leafhopper (*Edwardsiana rosae*), and two species of sawflies (Tenthredinidae) in blackberry. Naturally occurring predators sometimes contributed to control in blackberry. *N. californicus* did not establish in the strawberry greenhouses, and this could be due to competition from *N. cucumeris* and *Phytoseiulus persimilis* already present in the house. *N. cucumeris* seemed to be a significant spider mite predator in this experiment.

Key words: strawberry, blackberry, biological control, greenhouse, pests, *Neoseiulus*

Introduction

Freshmarket soft fruits grown in greenhouses out of season can fetch very high prices, and many growers are interested in exploiting this potential. However, the pioneering growers meet many challenges, such as developing suitable post harvest transport, knowing which climate regime will deliver berries at the scheduled time, securing sufficient pollination, and managing with the few (if any) pesticides registered for minor greenhouse crops.

In Norway, growers and other private enterprises with such problems can apply for financial support from the government to buy R&D suited their needs. To get support, they need to raise at least half of the sum required (for a large part this is made up by the value of their crop and production system, and the extra labour associated with the project), and to make contact with a research institution interested in carrying out the R&D. The number of such user-owned projects has increased the last years, and has contributed to a better mutual understanding between researchers and growers. However, it is not desirable that all research projects are of this type, because they tend to be small and biased towards the “D” in R&D, which gives poor opportunity for in-depth scientific study and publishable results (there may also be restrictions on publication).

In this paper I will present some results from two fruitful (in more than the literal sense) user-owned projects aiming at a more secure plant protection scheme in greenhouse berries, both with the Plant Protection Centre as R&D partner. The first project was on strawberries (August 1999 - May 2001). It consisted of four parts, one of them dealing with biological control of arthropod pests (Fløystad 2001; another part of the project included experiments
with Trichoderma products, see Hjeljord et al., 2000). The owner had several years of experience with greenhouse strawberries and biological control. Each year tended to bring a new pest, and at the time the project started, whiteflies were the main problem. We assisted the grower with pest identification and monitoring and suggestions of plant protection measures. In addition we did an experiment testing the establishment and preventive effect of the predatory mite Neoseiulus californicus. In accordance with general recommendations, the grower used this species preventively and Phytoseiulus persimilis curatively against spider mites (Tetranychus urticae). However, no tests of N. californicus (in any culture) had been carried out in Norway.

The second project, in blackberries, started in the autumn of 2000 and will be finished in 2002. It is owned by a local agricultural research and extension group in S-E Norway which serves the only three growers with greenhouse blackberries in the country. No pesticides are so far registered in this culture. The main project activities in addition to identification and monitoring are to collect information about potential pests and to try out various beneficials and other measures, in order to develop a pesticide-free plant protection scheme.

Material and methods

Strawberry pest control and monitoring
The strawberries were grown in two commercial greenhouses in the county of Østfold (S.-E., Norway), using hanging flats of sphagnum peat with 7 ‘Korona’ plants/m (1500 m² altogether). Each year, new plants were planted in August and harvested in three main periods: December, February and May (bud formation and flowering were induced by manipulating day length and temperature; Fløistad 2001). The temperature was set to 18-20°C when additional light was on, and 15-20 when not (the lower limits are for short day/ bud induction periods). The grower followed a biological control programme recommended by the provider of beneficials (L.O.G./Koppert). In addition to the spider mite control mentioned in the introduction this programme consisted of (pest in parentheses; preventive releases if nothing else is stated): Neoseiulus cucumeris in bags with Tyrophagus putrescentiae (strawberry mite Phytonemus pallidus; thrips Thrips spp), Hypoaspis aculeifer (soil living stages of thrips and dipterans), Steinernema feltiae (sciarids), Aphidius ervi in a cereal banker plant system with Sitobion avenae (“big greenhouse aphids” Macrosiphon and Aulacortum), A. colemani curatively (“small greenhouse aphids” Myzus etc), and Encarsia formosa and Eretmocerus eremicus curatively (glasshouse whitefly Trialeurodes vaporariorum). Climate control was used to minimise problems with fungal diseases (Botrytis, etc.), and calliphorid flies were pollinators.

From Oct 1999 to March 2001 the arthropod fauna in the greenhouses was registered in selected periods. The methods included picking of random leaves (usually 60 mature and 60 unfolded leaflets per house), yellow sticky traps, and inspection of unusual observations reported by the grower (who followed the plants very closely).

Experiment with N. californicus
The N. californicus experiment took place in one of the strawberry greenhouses during April 2000. At that time the spider mite population starts to increase as a response to higher temperatures and more light. Eleven flats were “pruned” (i.e. removing runners and senescent and/or spider mite infested leaves) and sprayed three times with an insecticidal soap, in order to knock down the mite fauna without pesticide residuals disturbing the experiment. The plants had flowers, so pollen was available for Neoseiulus mites. Plots consisting of 5 plants
were isolated by polystyrene plates in five of the flats (50 plots altogether). The rest of the pruned flats acted as buffers between experimental flats.

Plots received one of the following 5 treatments: A) High density of both *N. californicus* (10 individuals/plot) and *T. urticae* (6/plot); B) Low density of both *N. californicus* (5/plot) and *T. urticae* (3/plot); C) High *N. californicus* and low *T. urticae* density; D) Low *N. californicus* and high *T. urticae* density; and E) Control (no *N. californicus* and low *T. urticae* density). There were 10 replicates per treatment (2 replicates per flat). *N. californicus* (SPICAL, Koppert) was introduced by leaning glass tubes with five mobile mites against plants. *T. urticae* was collected elsewhere in the greenhouse and introduced the day after the predatory mites by placing leaflets with three mobile mites in the foliage (i.e. positioning the mite leaflet between plot plant leaflets). Leaves with *T. urticae* leaflets (one or two per plot) were marked. During the experiment the plants received constant additional light (i.e. 24h day length); but the temperature some days was lower (12-15°C in the day; 7-10 in the night) than scheduled. The RH was usually between 70 and 85%.

Four weeks after the spider mite introduction all marked leaves plus two random leaves per plant were taken to the lab. The number of dead (i.e. deflated) and living spider mites and predatory mites (not egg stage) were counted under a stereo microscope, and predatory mites of *Neoseiulus* type were slide-mounted and identified to species.

**Blackberry pest monitoring**
The three growers cultivate thornfree 'Loch Ness' in the county of Rogaland (S.-W. Norway), using sphagnum peat in plastic pots or polystyrene trays. The plant density is 1.2-1.5/m. Two of the growers have houses with heating (1100m² each), while the third grower uses an old 300 m² glasshouse without heating. The plants in the heated houses can be programmed for harvest in the period May-October, and after the break of winter dormancy in March the night/day temperature is set at 13-16/17-21°C. The cold house harvest is in July-August (break of dormancy in April). From each house random leaves and flowers were sampled twice a year (the last sampling also including berries in various stages) and sent to the Plant Protection Centre for identification of arthropods present.

**Results and discussion**

**Success and failure in strawberry biological control**
The biological control programme was very successful against strawberry mite and thrips, both of which had caused huge problems in earlier years (note that *Frankliniella occidentalis* was not present). During the project no thrips problems occurred, and only one small outbreak of strawberry mite. Aphid and spider mite control was also satisfactory for most of the time, but with a tendency of outbreaks towards the end of the season (April-May). Spider mite control demanded a rather high input of *P. persimilis* (the grower now uses monthly routine releases of 14 *P. persimilis* / m², plus extra in hot spots). The ‘Korona’ plants have a very generous amount of foliage, and may require more predators than usual. Besides, there was no help from *N. californicus* (see below).

The whitefly problem was not eased by the application of parasitoids. This could be due to the relatively low temperature, but a more likely explanation is the whitefly species involved, which was the honeysuckle whitefly *Aleyrodes lonicerae*, and not *T. vaporariorum*. Although *E. formosa* has been reared from *A. lonicerae* in the Netherlands (Lynch et al., 2001), not a single successfully parasitized *A. lonicerae* was observed in the present project. Repeated spraying with *Verticillium lecanii* (Mycotal) was tried in the 1999-2000 season, but without success (the combination of temperature and humidity probably was not in the *V.*
lecanii optimum). In the 2000-2001 season, plants were drenched with imidacloprid (Confidor) in September, after the plants were established and long before the first picking. Before drenching, old inactive leaves were removed to get rid of whitefly refuges. This strategy was successful. In addition the grower should eliminate A. lonicerae host plants (Rubus, Filipendula, Urtica) near the greenhouses.

**The N. californicus experiment**

The introduced spider mites established very well; spider mites were found on the marked leaves in 94% of the plots, compared with 8% of the random leaflets. *N. californicus*, however, did not establish; no *N. californicus* could be found; and the control plots did not have less spider mites than the plots with *N. californicus* (data not shown). The experiences with this species in strawberries are mixed (Meesters et al., 1998; Cross et al., 2001) and different climate, host plant suitability and *californicus* strains may explain this. The species survives well under British outdoor conditions (Easterbrook et al., 2001), so the climate alone cannot explain its failure in the present experiment (we also looked for it elsewhere in the greenhouses during the project without success). However, the two other phytoseiids used in the biological control programme were present in the experimental flats (on 500 random leaves, 49 *P. persimilis* and 55 *N. cucumeris* were found). This opens the possibility that the demise of *N. californicus* was brought on by competition (cf. Linder et al. elsewhere in this volume).

Both phytophagous and predatory mites were most numerous in plots positioned in the periphery of the experiment (Figure 2). Thus, the experiment was “polluted” by mites invading from the rest of the greenhouse as well as by mites surviving the soap treatment. The pollution illustrates the difficulties of performing experiments in a commercial greenhouse, but also the capacity for dispersal and survival in phytoseiid as well as tetranychid mites.

![Figure 1. The mite abundance on 10 random leaves (mean ± SE; 10 plots/flat) as a function of flat position 4 weeks after soap treatment. Phytoseiid numbers are true counts of *P. persimilis* + *N. cucumeris*, while *T. urticae* is the weighted sum of leaflets with mites present (double weight was given to leaflets with >10 living mites; half weight was given to dead mites).](image)

The number of predatory mites explained half of the variation in dead spider mite abundance, but had no relation to the abundance of living mites (Figure 2). This means that phytoseiid predation probably caused much of the observed mortality. The two phytoseiid species have almost overlapping regression lines (data not shown), which may suggest equal importance as predators.
Figure 2. Relation between phytoseiid counts and abundance of dead and living spider mites on 10 random leaves, n=50 plots (T. urticae index is the weighted sum of leaflets with mites present; leaflets with >10 mites are given double weight).

Table 1. Potential pests registered in blackberry (‘Loch Ness’) greenhouses Jan 2000- October 2001 and how they were dealt with. An ‘*’ means additional relevant information is given in the description of the biological control programme in strawberries (“Materials & methods”).

<table>
<thead>
<tr>
<th>Pest taxon</th>
<th>Measure tried</th>
<th>Results</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Root weevils Otiorhynchus</td>
<td><em>Heterorhabditis megidis</em> curatively</td>
<td>Good results</td>
<td></td>
</tr>
<tr>
<td>Spider mite T. urticae</td>
<td><em>P. persimilis</em> curatively, N. cucumeris preventively (Orius majusculus)</td>
<td>OK results</td>
<td>Not capable of being as destructive as in strawberries and raspberries? Predatory gall midge often invades</td>
</tr>
<tr>
<td>Thrips Thrips fuscipennis, flavus</td>
<td>(N. cucumeris, Orius)</td>
<td>Thrips are present, but not expected to be a problem in this culture</td>
<td></td>
</tr>
<tr>
<td>“Greenhouse aphids” *</td>
<td>Cereal banker plants with cereal aphids and <em>Aphidius</em></td>
<td>OK</td>
<td>Growers produce their own banker plants with cereal aphids</td>
</tr>
<tr>
<td>Berry aphids Aphis ruborum, Amphrophora rubi</td>
<td>Gall midge <em>Aphidoletes aphidomyza</em></td>
<td>Parasitoids does not work, nor gall midge?</td>
<td>Syrpids occurred in high numbers at the end of the largest outbreak (2000). Try <em>O. majusculus</em>?</td>
</tr>
<tr>
<td>Leafhopper Edwardsiana rosae</td>
<td>Yellow sticky traps Imidacloprid after harvest</td>
<td>?</td>
<td>At least 2 gen./year. Spraying after harvest 2001, long-term result remains to be seen next seson</td>
</tr>
<tr>
<td>Sawfly larvae Tenthredinidae</td>
<td>Removal of leaf litter during winter, yellow sticky traps</td>
<td>?</td>
<td>At least 2 gen./year. Susceptible to low doses of pesticides? (Gordon <em>et al.</em> 1997). Effect of leafhopper spraying?</td>
</tr>
<tr>
<td>Caterpillars Noctuidae</td>
<td>Some hand removal. Birds are also useful.</td>
<td>Not a big problem so far</td>
<td><em>Phlogophora meticulosa, Lacanobia oleracea</em> etc, capable of &gt;1 gen./year</td>
</tr>
</tbody>
</table>
Blackberry fauna and integrated control

The findings in the project so far are summarised in Table 1. The most troublesome pests are permanent blackberry aphid (*Aphis ruborum*), rose leafhopper (*Edwardsiana rosae*) and two unidentified species of sawflies (Tenthredinidae). The first two have been so serious that special permission had to be obtained for preventive spraying 2-3 weeks before harvest (reduced pirimicarb dosage against aphids) or spraying after harvest has ended (imidacloprid against leafhoppers). On the bright side, important pests such as blackberry mite *Acalitus essigi* and raspberry beetle *Byturus tomentosus* have not occurred.

Acknowledgements

I thank the growers (Irene & Svein Grimsby, Alf A. Bø, Kåre Bjerga, Ståle Runestad), my colleagues at the Norwegian Crop Research Institute (Ingrid Helleland, Nina Heiberg, Nina S. Johansen, Sverre Kobro, Annette Folkedal, Helen M. Singh), the advisors at the local research and extension groups (Eirik Stople, Annichen S.-Eriksen) and at the biocontrol supplier (Sveinung Grimsby, Sandra Mulder). The work was supported by the Agricultural Bank of Norway and the Agricultural Department of the County Governor for Østfold.

References


Resistance-breaking raspberry aphid biotypes: A challenge for plant breeding.

A. Nicholas E. Birch, A. Teifion Jones, Brian Fenton, Gaynor Malloch, Irene Geoghegan, Stuart C. Gordon, Jonathon Hillier, Graham Begg
Scottish Crop Research Institute, Invergowrie, Dundee DD2 5DA, Scotland, UK
1 BioSS, Dundee, DD2 5DA, Scotland, UK

Abstract: Resistance to the large raspberry aphid (*Amphorophora idaei*) in red raspberry, using single major genes or polygenic minor genes, has proved successful in controlling this virus vector aphid in Europe for the last thirty years. At present, c. 90% of raspberry UK plantations, valued at more than £28 million, contain varieties with these *A. idaei* resistance genes. Surveys done in the early 1990s found that more than more than 75% of the U.K. *A. idaei* population consisted of biotypes with the ability to break the most widely used resistance gene, *A*1. Since then growers in England (but not yet in Scotland) have reported intermittent breakdown of the formerly strongest resistance gene, *A*10. In this current growing season (2001), the incidence of *A. idaei* infestation on *A*10-containing varieties is increasing. Genetic analysis of raspberry aphid populations, based on rDNA IGS DNA patterns, has shown that *A. idaei* populations in the UK are genetically very variable within and between the 5 known *A. idaei* biotypes. This is attributed to alate migrations of parthenogenetic asexual females in summer and sexual males in autumn. This means that resistance-breaking genes are readily exchanged between raspberry aphid populations. It is therefore predicted that the *A*10 gene will be overcome throughout the UK within the next few years. Virus incidence is increasing in parallel with breakdown of the aphid resistance genes in U.K. raspberry plantations. Other aphid resistance genes are not readily available within the genus *Rubus*, although a search has continued. As an alternative source of resistance, anti-aphid genes from other plants (coding for plant lectins) have been genetically engineered into experimental plants. Initial risk:benefit assessment of one candidate aphid resistance transgene was presented, together with future prospects for introducing other sources of aphid resistance. The challenge to the fruit breeders and biotechnologists is initially to find durable resistance genes from other *Rubus* sources, either wild raspberry or closely related species. If acceptable to the general public, existing raspberry cultivars could later be modified with novel resistance genes from other sources, through genetic engineering. Aphid resistance has proved a valuable method of reducing insecticide use in red raspberry for more than 30 years, but the loss of pest resistance will result in increased pesticide use and make any Integrated Crop Management (ICM) more difficult. An important aim of ICM is to ensure that future pest resistance genes are compatible with beneficial natural enemies of raspberry aphids and other pests of *Rubus*.

Key words: *Amphorophora idaei*, resistance genes, *Rubus idaeus*, genetic variability, tri-trophic biosafety

Introduction

The large raspberry aphid, *Amphorophora idaei* Börner, is the most important vector in the U.K. and Europe of four viruses causing decline in vigour, yield and fruit quality of red raspberries. Pesticides control aphid numbers but are ineffective in preventing the spread of raspberry viruses. For more than 30 years the aphid and associated viruses have been effectively controlled using several major and minor genes for resistance to the aphid (Birch et al., 1994; Jones et al., 2000). The use of resistance genes has inevitably created selection pressure on *A. idaei* populations to overcome specific genes, leading to 5 resistance-breaking
aphid biotypes in the U.K. (Birch and Jones, 1988; Birch et al., 1994, 1997). Intra-specific genetic variability is maintained by sexual reproduction each autumn, with clonal (asexual) expansion of the surviving aphid genotypes during each summer (Birch et al., 1994). This reproductive strategy ensures that resistance-breaking genes can be spread between meta-populations of aphids and that adapted biotypes can rapidly expand through asexual reproduction. Countering rapid selection pressure for resistance-breaking aphid biotypes has probably been facilitated to some degree by several factors, mainly due to circumstance rather than strategic planning. These include the sequential release of different resistance genes over time, the use of mixed cultivar plantations (containing different aphid resistance genes), the host specificity of the aphid (no selection for resistance-gene breaking from other host plants) and by the reduced level of resistance (Jones et al., 2000) in lower, shaded leaves of resistant plants (enabling some aphids to survive in low numbers and sustain natural enemies). These factors may explain the longevity and durability of aphid resistance in Rubus until recently, compared with durability of some other pest-resistant crops.

Materials and methods

Methods for screening raspberry cultivars for aphid resistance and for detecting A. idaei biotypes are published in Birch and Jones, 1988 and in Jones et al., 2000. Methods for analysis of genetic variability within and between populations of A. idaei are published in Birch et al., 1994. Risk:benefit analysis of introduced insect resistance genes on target pests (e.g. aphids) and on non-target natural enemies of aphids (e.g. 2-spot ladybirds) are published in Birch et al., 1999.

Results and discussion

Natural resistance genes from Rubus spp.
Both glasshouse (excised leaves, whole plants) and field-based methods for screening aphid-resistant progeny plants from crosses work well, provided the environmental conditions are suitable (well lit, temperature between 15 and 20°C) and control plants (susceptible and resistant parent plants) are included. The threshold for scoring resistance is generally very low (0-1 adults, < 3 nymphs, after 10 days). Bioassays and chemical analyses (Birch and Jones, 1988; Shepherd et al., 1999) showed that the chemical factor(s) in A1 and A10-based resistance were complex and located on the leaf surface, causing aphids to reject plants within 24 hours, after initial landing and probing of leaf surface and internal tissues.

Aphid biotypes which could overcome A1-based resistance were detected in large numbers (>70% of samples) in both England and Scotland during the 1980s and 1990s (Birch et al., 1994), whereas the A10-breaking biotype has only been detected more recently in parts of England but is not yet established in Scotland (Birch et al., 1997), although small numbers of raspberry aphids have been detected on isolated plants of A10-containing cv. Glen Rosa at SCRI experimental plots in 2000 and 2001. A wide range of raspberry aphid genotypes were detected in U.K. populations of A. idaei using rDNA IGS markers (Birch et al., 1994), highlighting the capacity for this host-specific aphid to readily exchange genes between populations each year during the sexual reproductive cycle.

Transgenic resistance genes from other plants (transgenes coding for lectins)
Whilst several plant lectins were shown to be effective in reducing aphid populations by up to 50% under contained conditions, this degree of resistance was insufficient on its own, particularly against virus vector aphid species. Bioassays to check the compatibility of aphid
resistance based on the snowdrop lectin (GNA), expressed in experimental lines of transgenic potato, showed adverse effects on a beneficial aphid predator species, the 2-spot ladybird *Adalia bipunctata* L. (Birch et al., 1999). Ladybirds fed aphids from GNA-expressing plants were adversely affected in terms of their fecundity (egg fertility and hatch rates) as well as suffering a 50% reduction in female adult ladybird longevity. Thus, tri-trophic biosafety testing (resistant plant, target pest and non-target predator) was shown to be important in the risk:benefit assessment of novel aphid resistance genes. The lectin genes tested to date were considered to be unsuitable candidates for insertion into *Rubus* to protect against *A. idaei*, because of their lack of efficacy against target pests and their potential toxicity to non-target organisms, including humans (Birch et al., 1999; Fenton et al., 1999).

Aphid resistance genes have been very successfully deployed in *Rubus idaeus* for more than 30 years in Europe. Not surprisingly, raspberry aphids have counter-adapted over this time and we are now at the point where our last major resistance gene (*A10*) has been overcome in much of England and at least one isolated case in Scotland (Birch et al., unpublished data). With the benefit of hindsight we can look back and learn important lessons concerning the choice and deployment of aphid resistance genes. We may still be able to combine some of our existing genes from *Rubus* (e.g. minor gene and major gene-based resistance), particularly with the help of molecular markers. Alternatively, we may find and introduce novel aphid resistance genes from other plant genera or even other organisms, via biotechnological routes. Whichever way we proceed, it is important that we think carefully about risk:benefit ratios and how any new aphid-resistant cultivars fit into the wider view of sustainability and durability within an Integrated Pest Management (IPM) framework. Mathematical models are now also being developed at SCRI as tools to predict the optimal deployment of pest resistance genes over space (fields, regions) and time (seasons).

**Acknowledgements**

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**References**


Monitoring and importance of wingless weevils (*Otiorhynchus* spp.) in European red raspberry production

Stuart C. Gordon¹, J. A. Trefor Woodford¹, Alberto Grassi², Matteo Zini², Tuomo Tuovinen³, Isa Lindqvist³, James W. McNicol⁴

¹ Scottish Crop Research Institute, Invergowrie, Dundee DD2 5DA, Scotland UK
² Istituto Agrario Provinciale di S. Michele all'Adige, Via Edmondo Mach 1, I-38010 S. Michele a/Adige, Italy
³ Agrifood Research Finland, FIN-31600 Jokioinen, Finland
⁴ Biomathematics and Statistics Scotland, Scottish Crop Research Institute, Invergowrie, Dundee DD2 5DA, Scotland UK

Abstract: Wingless weevils (*Otiorhynchus* spp.) are widespread in red raspberry (*Rubus idaeus*) in several regions of Europe. One objective of a 2-year EU-Craft/BBW (Switzerland)-funded project 'Reduced Application of Chemicals in European Raspberry Production (RACER)' was to develop and test simple trapping methods to permit growers to detect the nocturnally active adult weevils in raspberry plantations. Wooden groove traps (30 x 30 cm, with 8 mm wide and 8 mm deep grooves cut on the underside), and 50 x 50 cm fabric traps (black landscape fabric) were compared with diurnal and nocturnal beating. The species found at each geographical location were identified. In Finland, *O. ovatus* and *O. nodosus* are frequently found in strawberry plantations but groove traps and fabric traps failed to trap any weevils in fields adjacent to strawberry in 1998. In 1999, modified groove traps (4 x 4 mm grooves) at three sites only caught a very small number of *O. ovatus*. Both diurnal and nocturnal beating of the plants failed to detect weevils. These and other records suggest that wingless weevils are not common in raspberry in Finland. In Scotland, the main species associated with raspberry is the clay-coloured weevil (*O. singularis*), but vine weevils (*O. sulcatus*) were also detected. Nocturnal sampling was to be the most effective method of detecting these weevils, although small numbers were found in the grooved traps. In 1999, a hand-held beating tray, as developed for the WSU Nooksack IPM Project in the USA, was tested and proved a convenient method for detecting weevils, but could only be used effectively after dark. In Italy, both summer and autumn fruiting raspberry plantations were examined for weevils. Seven *Otiorhynchus* spp. were identified. The most abundant were *O. apenninus*, *O. sulcatus*, *O. armadillo*, *O. ovatus* and *O. globus*. Crop scouting and nocturnal beating were the most effective methods to detect adult weevils. *O. apenninus*, *O. armadillo*, *O. ovatus* and *O. sulcatus* were considered to be damaging to raspberry plants.

Key words: clay-coloured weevil, vine weevil, life cycle, Italy, Finland, UK

Introduction

Several wingless weevils of the genus *Otiorhynchus* (Coleoptera: Curculionidae) have become serious pests of temperate horticulture (Figure 1), the most notable being the vine weevil (*O. sulcatus*) which damages a wide range of plants (Moorhouse et al., 1992). Of those that damage soft fruits, the most damaging to raspberry are the clay-coloured weevil (*O. singularis*) (Cameron, 1936; Gordon and Woodford, 1987; Tanigoshi and Bergen, 2002) and to a lesser degree, the red-legged weevil (*O. clavipes*) (Alford, 1984). The rough strawberry weevil (*O. rugosostriatus*) and the strawberry weevils (*O. ovatus* and *O. rugifrons*) all damage strawberry. The importance of *O. sulcatus* has increased dramatically over the last 20
years following the withdrawal of persistent insecticides such as aldrin and DDT, the change from bare-rooted nursery stock to containerised planting and the use of polythene mulches (Moorhouse et al., 1992). Most wingless weevils adults are nocturnal feeders causing characteristic notching to the leaves of most host plants. Although weevils feed on foliar parts of the raspberry the typical leaf notching that characterises this group of insects is not always evident.

Figure 1. The approximate worldwide geographical distribution of the main damaging wingless weevils (after Moorhouse et al., 1992)

One of the main aims of the ‘Reduced Application of Chemicals in European Raspberry Production’ (RACER) Project, funded by the EU-CRAFT and BBW (Switzerland) was to
develop a monitoring system for growers to determine weevil activity in their raspberry plantations so that appropriate weevil management treatments could be applied. This paper reports the procedures and results of this task.

Life cycle of wingless weevils

The life cycles of wingless weevils are very similar. Most species consist solely of females, no males being found, whose eggs are viable without needing to be fertilised (parthenogenic females). Most feed nocturnally and shelter in the soil or in dense foliage during the day. After adult emergence in spring or early summer there is often a period of intense feeding followed by egg laying. A single weevil may lay several hundred eggs during her life. The larvae feed on plant roots until the next spring when they pupate before emerging as adults to start the cycle again, albeit with some overlap between generations (Tanigoshi and Bergen, 2002).

Material and methods

Observations were done in three countries, Finland, Italy and the UK (Scotland) for two years, 1998 and 1999. The numbers of observation sites varied in each year. Plantations examined for weevil activity were chosen because either they had a record of damage or were very close to a site with a history of damage. Groove and black fabric (Table 1) were placed in the centre of the raspberry row and examined on several occasions during daylight hours. Nocturnal beating was usually done one or two occasions as were diurnal beating. All trapping and/or beating were done when weevils were known to be active in the sample crops or in the surrounding area. Initially three basic trapping methods were used. In the second year modifications or alternative collection methods were used (Table 1). The modified Nootsack beating tray was used after dark in the UK.

Results and discussion

Only selected data is presented here to illustrate the relative effectiveness of the different types of trap used at different geographical locations.

In Finland, very low numbers of weevils were detected in the raspberry plantations although they were adjacent to strawberry plantations where *O. ovatus* and *O. nodosus* were common. *O. ovatus* is one of the smaller wingless weevils found associated with soft fruit but replacing 8 mm wide grooves in the groove traps with 4 mm wide grooves did not improve the collection of weevils. Nocturnal and diurnal beatings also failed to detect weevils. It can therefore be concluded that wingless weevils have not reached pest status in raspberry in Finland.

In Italy, the range of species found on raspberry was considerably higher than elsewhere (Table 2). This is not unexpected as the Trentino region is in the mountainous north of Italy close to the southern flanks of the European Alps, which may to be the centre of biodiversity for this group of insects (Magnano, 1998). The levels of damage were also high in Italy with some plantations with canes being severely stunted due to larval feeding *O. armadillo, O. ovatus* and *O. sulcatus*, but not by the other species. Plant beating, both nocturnal and diurnal, was the most effective method of collecting weevil adults. Table 3 shows the results from one site in 1999. It is difficult to equate precisely the effective surface area of raspberry row affected by each trap type due to their position within the row and to the weevil behaviour at
time of sampling. Clay-coloured weevils are widely dispersed along the length of the row and when sampled at night most of the weevils in a 2 m row length are collected.

Table 1. Details of trapping systems used to detect wingless weevils.

<table>
<thead>
<tr>
<th>Trap Type</th>
<th>Year/s</th>
<th>Construction Details</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groove (8mm)</td>
<td>1998/9</td>
<td>30 x 30 cm (0.09 m²) plywood board with lattice of 10 x 8 mm wide grooves on underside</td>
<td>Li et al., 1995</td>
</tr>
<tr>
<td>Black Fabric</td>
<td>1998</td>
<td>50 x 50 cm (0.25 m²) black landscape fabric held in position by wire pins</td>
<td>N/A</td>
</tr>
<tr>
<td>Nocturnal Beating (white sheet)</td>
<td>1998/9</td>
<td>2 x 0.5 m strips of white, light weight poly-propylene ground cover fabric on each side of row (equivalent to 1 m² raspberry row) (modification of traditional method)</td>
<td>Theobald, 1909</td>
</tr>
<tr>
<td>Modified ‘Nootsack’ Beating Tray</td>
<td>1999</td>
<td>44.5 x 43 cm 15 mm i.d. copper pipe frame with 23 cm handle covered with white brushed nylon fabric (UK only)</td>
<td>Menzies and MacConnell, 1998</td>
</tr>
<tr>
<td>Groove (4mm)</td>
<td>1999</td>
<td>30 x 30 cm plywood board with lattice of 10 x 4 mm wide grooves on underside (only in Finland)</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Table 2. Most common wingless weevil species found in the different countries, levels of damage and their relative frequency.

<table>
<thead>
<tr>
<th>Country</th>
<th>Species</th>
<th>Damage</th>
<th>Relative Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finland</td>
<td><em>Otiorhynchus ovatus</em></td>
<td>None</td>
<td>Rare</td>
</tr>
<tr>
<td>Italy</td>
<td><em>O. armadillo</em></td>
<td>Moderate-severe</td>
<td>Locally common</td>
</tr>
<tr>
<td></td>
<td><em>O. apenninus</em></td>
<td>Slight</td>
<td>Locally common</td>
</tr>
<tr>
<td></td>
<td><em>O. globus</em></td>
<td>Slight</td>
<td>Locally common</td>
</tr>
<tr>
<td></td>
<td><em>O. ovatus</em></td>
<td>Moderate-severe</td>
<td>Common</td>
</tr>
<tr>
<td></td>
<td><em>O. sulcatus</em></td>
<td>Moderate-severe</td>
<td>Common</td>
</tr>
<tr>
<td>UK (Scotland)</td>
<td><em>O. singularis</em></td>
<td>Moderate-severe</td>
<td>Common, locally abundant</td>
</tr>
<tr>
<td></td>
<td><em>O. sulcatus</em></td>
<td>Slight</td>
<td>Common, low numbers</td>
</tr>
</tbody>
</table>

Inspection of the groove and fabric traps was done during daylight when the weevils had returned to the soil to shelter and those caught only represent a small proportion that would be on the canes at night. The groove traps did catch some weevils and this could be used as an indicator, but the number of traps required to get a reasonable assessment of the population may be too great. The black fabric traps were very inefficient. Therefore, as a part of monitoring procedure, nocturnal beating has the advantage that a relatively large area is
sampled and this should pick up low density of weevils. Additionally, an estimate of weevil density can usually be acquired on one sampling occasion.

Table 3. Number of wingless weevils caught at three sites in northern Italy in 1999 using different sampling methods.

<table>
<thead>
<tr>
<th>Site</th>
<th>Species</th>
<th>Number of weevils</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Groove</td>
</tr>
<tr>
<td>A</td>
<td><em>O. armadillo</em></td>
<td>2</td>
</tr>
<tr>
<td>B</td>
<td><em>O. globus</em></td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td><em>O. apenninus</em></td>
<td>2</td>
</tr>
</tbody>
</table>

Table 4. Numbers of wingless weevils caught at one site in eastern Scotland in 1998 using different trapping methods.

<table>
<thead>
<tr>
<th>Date</th>
<th>Species</th>
<th>Number of weevils</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Groove (0.09 m²)</td>
</tr>
<tr>
<td>13 May 1998</td>
<td><em>O. singularis</em></td>
<td>5</td>
</tr>
<tr>
<td>14 May 1998</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>20 May 1998</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>26 May 1998</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>3 June 1998</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>9</td>
</tr>
</tbody>
</table>

Table 5. Total number of wingless weevil caught at six sites in eastern Scotland in spring 1999 using different sampling methods.

<table>
<thead>
<tr>
<th>Site</th>
<th>Number of weevils caught (<em>O. singularis</em> and <em>O. sulcatus</em>)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Groove (0.09 m²)</td>
</tr>
<tr>
<td>A</td>
<td>11</td>
</tr>
<tr>
<td>B</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>41</td>
</tr>
<tr>
<td>D</td>
<td>0</td>
</tr>
<tr>
<td>E</td>
<td>0</td>
</tr>
<tr>
<td>F</td>
<td>48</td>
</tr>
</tbody>
</table>

Other methods of trapping wingless weevils (usually vine weevil) have been used on other crops. Pitfall traps have been used to assess adult weevil activity in yew (*Taxus* sp.) (Hanula, 1990), and in strawberry (Graham et al., 2002). Although both systems caught weevils, pitfall trapping was too complex for monitoring raspberry. Corrugated cardboard tree wraps (Phillips, 1989) and cardboard wafers (Hanula, 1990) were rejected on the same grounds. The Nooksack beating method is recommended as a day-light sampling method in Washington State, but it could only trap weevils when used as part of nocturnal beating in Scotland. This is largely due to the behaviour of clay-coloured weevil and the differences in
raspberry husbandry. In Washington State, raspberry canes are bundled together, bent over and tied to the support wire in a dense mass of foliage permitting weevils to shelter in the canes and foliage (Tanigoshi and Bergen, 2002), whereas in the UK canes are grown in a ‘fan’ shape. The foliage is very much more open and weevils are forced to move to ground level to shelter during the day.

Acknowledgements

We thank the many growers who participated in this project and the staff in the participating SMEs for their time and input and all the research staff at the various Research Establishments for their hard work and dedication. We also thank the EU (FAIR FA-S2-CT97-9038) and Bundesamt für Bildung und Wissenschaft (BBW) for funding the project. SCG is funded by the Scottish Executive Environment and Rural Affairs Department (SEERAD).

References

Field application and effectiveness of commercial entomopathogenic nematode formulations against *Otiorhynchus armadillo* subsp. *obsitus* Gyllenhal (Coleoptera: Curculionidae) larvae on raspberry

Alberto Grassi, Romano Maines, Matteo Zini

*Istituto Agrario di S. Michele all'Adige, Via Edmondo Mach 1, I-38010 S. Michele a/Adige (TN), Italy*

**Abstract:** Otiorhynchid weevils are a new pest on red raspberry in the Trentino alpine region of Italy. Of the eleven species recorded, *Otiorhynchus armadillo* subsp. *obsitus* seems to be the most harmful to the plantations. A biological control experiment with entomopathogenic nematodes was carried out in 2000 in a 3 year-old red raspberry plantation infested by *O. armadillo* subs. *obsitus* adults and larvae. *Steinernema feltiae* and *Heterorhabditis megidis* commercial formulations were compared with a control block, treated with water. Mortality following treatment was 60.29% for *H. megidis* and 16.95% for *S. feltiae*. The result with *H. megidis* is particularly encouraging in view of the relatively low mean soil temperatures (around 14-15 °C) after the treatment, and the practical distribution system, which could be readily adopted by growers. Further trials are needed to improve field application (e.g. decreasing nematode retention in the irrigation system), to time correctly the treatment with regard to the biological cycle of each species and to evaluate the effectiveness of other nematode species.

**Key words:** Otiorhynchid weevils, *Otiorhynchus armadillo* subsp. *obsitus*, entomopathogenic nematodes, *Steinernema feltiae*, *Heterorhabditis megidis*, red raspberry, distribution system

**Introduction**

During the EU-CRAFT project RACER (Reduced Application of Chemicals in European Raspberry Production), adults of 11 wingless weevils species were caught on red raspberry in the Trentino alpine region in Italy. The most numerous species were *Otiorhynchus apenninus* Stierlin, *O. sulcatus* (F.), *O. armadillo* subs. *obsitus* Gyllenhal, *O. globus* Boherman, and *O. ovatus* (L.). The relationships of these populations with the cultivated host were the object of preliminary further investigations.

The typical feeding notches caused on leaf margins by the adults of each species resulted in negligible damage, even for the voracious *O. armadillo*. Larval populations and associated damage were recorded on roots of those raspberry plants infested by *O. sulcatus*, *O. ovatus* and *O. armadillo* adults. Therefore, these species can be considered as new important pests of red raspberry in Trentino.

Young plantations are more susceptible, since the root system is more delicate and some plants may die. Established raspberry plantations seem to tolerate infestations, but it is likely that larval activity year after year may depress vegetative vigour, gradually reduce plant productivity and increase the susceptibility of the root system to fungi. Damage thresholds are still not established: 3-5 larvae/plant may be a reasonable provisional attention level, especially on young plantations and for *O. sulcatus* (F.) infestations.
In Trentino, selective and effective IPM suitable chemicals to control wingless weevils adults or larvae are not available to growers, but an effective monitoring system and procedure for adults was tested during RACER project.

Entomopathogenic nematodes are widely used and effective against *O. sulcatus* on strawberry and ornamental plants. The application system is the key to the success and uptake of this control method. It must be easy for the grower to use and must guarantee optimal operating conditions to the nematodes.

In this trial we compared the effectiveness of two commercial entomopathogenic nematode formulations against *O. armadillo* larvae in the field when applied by the most common irrigation system in this region.

**Material and methods**

**Trial site**

The trial was made in a sandy field of 500m² at about 800 m above sea level. The raspberry plants (cv. Heritage, 3 years old) were arranged in 6 rows (46 m long), 1.6m apart and 30cm between plants in the row. A polythene covering was erected in July during fruit ripening, creating 2 tunnels. Water was supplied by a "drop to drop" irrigation system, constructed of wide flexible PVC tubes (20mm diameter), running along the rows at about 5-10 cm above the soil level and in the middle of each row. Every 30 cm there was an outlet, with a labyrinth of channels inside the tape. Each irrigating line was fed from a main head-line (32mm diam.), placed at the top of the field, and could be isolated from the supply by operating a valve.

**Nematode application**

*Steinernema feltiae* (Entonem) and *Heterorhabditis megidis* (Larvanem), both supplied by Koppert, were compared with a control block, treated with water, in two replications.

After three days of continuous irrigation, approximately 83,000 nematodes/metre were distributed on 21 September. On the day of treatment, nematode formulations were accurately dissolved in 10 litres of water at external temperature. This solution was mixed continuously (Kakouli-Duarte et al., 1997) and the desired rate was added to 50 L of water in the fertiliser holding tank, and distributed to the selected replication. The slope between tank and irrigating lines provided the working pressure (less than 1 bar). An additional four days of continuous irrigation followed the treatment to facilitate nematode movement and searching for the weevil larvae. During the treatment, about 50 ml of water was sampled from two outlets (at the beginning and at the end of the line), and the homogeneity of the distribution and nematode viability were checked later in the laboratory (Kakouli-Duarte et al., 1997). Soil temperature data at 10 cm depth were collected from a meteorological station close to the trial site.

**O.armadillo larvae sampling**

Larval infestation was assessed before (4 September) and after treatment (3 October). On each occasion, 8 samples of soil were randomly collected from each replication. A sample was the soil collected from a 25x25x25 cm depth hole made around a stump root. Larvae were extracted from the soil sample by a modified floatation system; water at high pressure (about 5 Bar) was sprayed in the middle of a sub-sample of about 3 L of soil in a container. Then, rapidly the water was filtered through a fine mesh sieve. Larvae were collected from the sieve and measured. Dead larvae were placed on water-traps to assess nematode infestations. A sample of 20 live larvae from both replications of each block was reared in laboratory (at c.20°C) for 24 days to assess if they were infected by nematodes. Larvae were placed singly
in pots filled with sterile soil kept moist. Carrot discs, renewed every 4 days, were used as food.

**Result and discussion**

*H. megidis* was significantly more effective than *S. feltiae* in reducing the number of *O. armadillo* larvae in the soil (Table 1). A few of the live larvae in the rearing tests were subsequently killed by *H. megidis* (Table 2), indicating that some larvae avoided the nematodes in the soil and confirming recorded mortality data.

Table 1. Pre and post application summarised sampling data

<table>
<thead>
<tr>
<th>Treat.</th>
<th>Mean n° of alive larvae/plant</th>
<th>Effectiv. (*)</th>
<th>Mean n° of alive larvae of 2-3 mm length/plant</th>
<th>Mean n° of alive larvae of 4-5 mm length/plant</th>
<th>Mean n° of alive larvae of 6 and &gt; mm length/plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check</td>
<td>3.8</td>
<td>7.4</td>
<td>2.18 (57.4%)</td>
<td>2.5 (33.9%)</td>
<td>1.31 (34.4%)</td>
</tr>
<tr>
<td><em>H. megidis</em></td>
<td>4.3</td>
<td>3.3</td>
<td>1.37 (31.9%)</td>
<td>1 (30.2%)</td>
<td>2.12 (49.3%)</td>
</tr>
<tr>
<td><em>S. feltiae</em></td>
<td>3.8</td>
<td>6.1</td>
<td>1.75 (45.9%)</td>
<td>1.87 (30.6%)</td>
<td>1.75 (45.9%)</td>
</tr>
</tbody>
</table>

(*) Effectiveness was calculated with Henderson and Tilton formula:
\[ \text{% of mortality} = \frac{(1 - [(k1xp2)/(k2xp1)]) \times 100}{k1=\text{alive larvae on check plot (the mean value of replications) before treatment}} \]
\[ k2=\text{alive larvae on check plot (the mean value of replications) after treatment} \]
\[ p1=\text{alive larvae on treated plot (the mean value of replications) before treatment} \]
\[ p2=\text{alive larvae on treated plot (the mean value of replications) after treatment} \]

While *S. feltiae* is recommended for the control of sciarid fly larvae, *H. megidis* is more effective against Curculionidae larvae, such as black vine weevil, *Otiorhynchus sulcatus*. Moreover, the different effectiveness achieved with the two genera may be due to their different host penetration and foraging strategies. *Steinernema* spp. use body openings, i.e. mouth, anus and spiracles, to enter the host, whereas *Heterorhabditis* spp. are able to penetrate the host directly through the cuticle, which they open with a sclerotised dorsal tooth (Kakouli-Duarte et al., 1997). The better performance of heterorhabditids over steinernematids has been noted by numerous authors and in a previous experiment carried out by us in 1994 to control *O. sulcatus* and *O. ovatus* on strawberry.

The mortality caused by *H. megidis*, which was recorded only 12 days after application, indicates a particularly fast action of infective juveniles in this formulation in our trial conditions.

An increase in effectiveness, due to a new generation of infective *H. megidis* juveniles, might be expected in the days following the post-application monitoring, as long as favourable conditions for the nematodes could be guaranteed (especially water content in the soil). Later sampling would have been useful to document the complete effectiveness of this formulation.
The performance of *H. megidis* has to be considered as particularly encouraging, considering the conditions at the time of treatment, the biology of the target pest, and the system of application adopted.

With regard to biology, *O. armadillo* subs. *obsitus* was unknown as a pest on agricultural crops before the RACER project. New information has been obtained during the RACER project and the current trial.

Table 2. Data of rearing of live larvae collected from soil sample in the post-application control.

<table>
<thead>
<tr>
<th>Treat.</th>
<th>Nº of larvae reared</th>
<th>Nº of dead larvae after 4 days</th>
<th>Nº of dead larvae after 8 days</th>
<th>Nº of dead larvae after 24 days</th>
<th>Total Nº of larvae killed by nematode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check</td>
<td>20</td>
<td>1 (*)</td>
<td>3 (2*)</td>
<td>4</td>
<td>3 (15%)</td>
</tr>
<tr>
<td><em>H. megidis</em></td>
<td>20</td>
<td>1 (*)</td>
<td>3 (2*)</td>
<td>5</td>
<td>3 (15%)</td>
</tr>
<tr>
<td><em>S. feltiae</em></td>
<td>20</td>
<td>0</td>
<td>1 (*)</td>
<td>6</td>
<td>1 (5%)</td>
</tr>
</tbody>
</table>

(Nº*) = Nº of larvae killed by nematodes; another cause of mortality was fungi development on carrot pieces. On check plot, 15% of reared larvae were killed by unidentified indigenous nematodes.

Check plot data (Table 1) suggest, for example, that the larval population peaks rather late in the season, in September/October, since numbers almost doubled in the period between pre- and post-application sampling.

Moreover, it is likely that most larvae overwinter in the last stages because the distribution of larvae in the largest empirical size classes showed the biggest increase in the same period. In 1999, adults emerged over a long period, from the end of April until the beginning of October, and that might be explained by a considerable proportion of small larvae remaining at the end of the season.

Table 3 shows that about 84% of dead red larvae (killed by *H. megidis*), collected from Larvanem block in the post-application sample were at least 4 to 6 mm in length. This susceptibility of the biggest larvae to be infected by nematodes is probably due to their major emission of CO₂ compared with small larvae, since nematodes are attracted by this compound.

This information suggest that treatment with *H. megidis* would be more effective if it is applied in the following spring, when all larvae are in the last stages of their development. However, the grower would have to tolerate larval damage in the meantime (Kakouli-Duarte et al., 1997). Moreover, mean daily soil temperature in our climate do not exceed 10°C (minimal soil temperature recommended for nematodes distribution) until the end of April, when adults start to emerge. A delayed autumnal application (October), in order to control the largest larvae, may encounter problems due to decreasing soil temperatures (the mean daily soil temperature in October was 10-11°C).

For these reasons, nematode treatment is not easy to time correctly. The end of September/beginning of October seems to be the most suitable period. Nematodes active in cold temperatures may be particularly useful, since they would permit late treatment.

The application method adopted was partially successful. No mortality of nematode infective juveniles was observed in the solution samples collected at the exit outlets. The mortality result indicates a good distribution of the solution, and this system was really easy to use.
Table 3. Mean numbers of dead larvae in three size classes (in brackets, % of total dead larvae in that treatment)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean n° of dead larvae/plant</th>
<th>Mean n° of dead larvae of 2-3 mm length/plant</th>
<th>Mean n° of dead larvae of 4-5 mm length/plant</th>
<th>Mean n° of dead larvae of 6 and &gt; mm length/plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check</td>
<td>0.62</td>
<td>0.06 (10%)</td>
<td>0.25 (40%)</td>
<td>0.31 (50%)</td>
</tr>
<tr>
<td><em>H. megidis</em></td>
<td>0.75</td>
<td>0.12 (16.6%)</td>
<td>0.25 (33.4%)</td>
<td>0.37 (50%)</td>
</tr>
<tr>
<td><em>S. feltiae</em></td>
<td>0.37</td>
<td>0.06 (16.7%)</td>
<td>0.18 (50%)</td>
<td>0.12 (33.3%)</td>
</tr>
</tbody>
</table>

Nevertheless, the irrigation system used in this trial may have affected *H. megidis* performance because the nematode solution was retained in the head line during application. It was estimated that about 7.2% and 4.8% of the released nematodes might have been trapped in the part of the head line between the end valve and the selected replication in the first and second replication, respectively. This problem might have been avoided by filling that section with water before adding the nematode solution, and increasing working pressure. Another problem, due to bad alignment of the line outlets with the base of some plants, was that some roots might have received only a few or no nematodes, despite abundant irrigation. Most studies indicate that nematodes tend to stay close to the point of application, so migration to distant larvae is very limited (Kakouli-Duarte et al., 1997; Curran, 1992; Kaya and Gaugler, 1993).

Moreover, while sandy soil composition may have helped the vertical dispersion of the solution, and enabling nematodes to reach larvae deep in the ground, it may not have helped horizontal dispersion of solution. The wet zones may have not have been closely linked to the parts of the soil profile occupied by most of roots and larvae.

Dead leaves and material on the soil surface around the plants may also have delayed or seriously hampered the migration of nematodes inside the soil, exposing them to the risk of desiccation.

In order to avoid these problems, a higher rate of nematode application may be necessary.

An increase of natural mortality in the check plots after abundant irrigation, due to indigenous nematodes (Table 2 and 3) indicates that these local species may co-operate with commercial ones to control Otiorhynchid weevil larvae in good operating conditions.

Results of this trial suggest that growers can rely on *Heterorhabditis megidis* to effectively limit *O. armadillo* infestations or outbreaks on red raspberry.

From an economical and environmental point of view, it is a competitive method if compared with other control measures (Kakouli-Duarte et al., 1997).

The "drop to drop" irrigation system greatly simplifies distribution and guarantees a considerable effectiveness of the nematodes provided that it is well arranged (Kramer & Grunder, 1998) with a working pressure not less than 1 bar, retention in the irrigation line is avoided or minimised, the soil is kept constantly wet before and after nematode application; it is important that the nematodes are distributed just before mean soil temperature falls below a minimal application threshold of 10 °C.

In order to improve the application strategy, biology of the target weevil species must be further studied, especially regarding overwintering forms (Fuxa, 1987). Research and experimentation must also be focused on alternative cold active nematode species that may be more suitable for our requirements (Kaya and Gaugler, 1993).
Acknowledgements

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References

Commercial breeding for pest and disease resistance in cane and bush fruits

S. Nikki Jennings\textsuperscript{1}, Rex Brennan\textsuperscript{2}, Stuart C. Gordon\textsuperscript{2}
\textsuperscript{1}Mylnefield Research Services Ltd, Invergowrie, Dundee DD2 5DA, Scotland, UK
\textsuperscript{2}Scottish Crop Research Institute, Invergowrie, Dundee DD2 5DA, Scotland, UK

Abstract: Although breeding for agronomic traits remains a priority in any commercial breeding programme, a key objective of the \textit{Rubus} breeding programme, implemented by MRS, is to incorporate resistance/tolerance to pest and disease. Over 90\% of the germplasm is segregating for the gene A\textsubscript{10c}, conferring resistance to four biotypes of the large raspberry aphid (\textit{Amphorophora idaei}). This aphid is a vector of several important viral diseases and resistance has played an important part in increasing the longevity of modern raspberry plantations. With the risk that this resistance gene may be overcome by resistance breaking strains, new sources of resistance are being sought.

Raspberry root rot, caused by the fungus \textit{Phytophthora fragariae} var. \textit{rubi}, continues to be the most destructive disease of raspberries in Scotland. Approximately 25\% of the breeding programme is dedicated to breeding for resistance or tolerance to \textit{Phytophthora} using resistance genes from \textit{R. strigosus}. Genotypes have been identified with putative resistance and these are undergoing further evaluation to enable the eventual release of a tolerant variety with commercial fruit quality.

Future breeding plans with respect to \textit{Phytophthora} resistance are underpinned by the development of molecular markers to improve and accelerate selection efficiencies.

In the case of \textit{Ribes}, the recent release of cultivars from SCRI with resistance to gall mite (\textit{Cecidophyopsis ribis}) and blackcurrant reversion virus has increased the potential for the commercial growing of blackcurrants under low-input and ICM systems. Further resistant seedlings are currently in commercial trials.

AFLP markers linked to the \textit{Ce} gene for gall mite resistance have been identified, and appropriate deployment strategies for this and other molecular markers (mainly SSRs) currently under development will accelerate the identification and eventual release of new resistant hybrids. However, diversification of the pest and disease resistance genes is essential for the future success of the SCRI \textit{Ribes} programme.

Key words: raspberry, blackcurrant, large raspberry aphid, \textit{Amphorophora idaei}, raspberry root rot, \textit{Phytophthora}, blackcurrant gall mite, \textit{Cecidophyopsis ribis}

Introduction

Raspberries have been bred at Mylnefield since the 1950s and the development of cultivars crucial to the industry’s prosperity has continued at SCRI to the present time. SCRI-bred cultivars currently occupy 96\% of the raspberry market in Scotland and ‘Glen Ample’ has established itself as the most widely grown cultivar in the UK.

Under commercial funding from the growers’ cooperative, Scottish Soft Fruit Growers Ltd., from 1993 until 2000, the breeding programme focussed on producing cultivars adapted to Scottish conditions that had improved fruit quality, yield, tolerance to pest and disease, and were adapted to machine harvesting.

Although breeding for agronomic traits remains a priority in any commercial breeding programme, a key objective of the \textit{Rubus} breeding programme is to incorporate resistance/tolerance to pest and disease and make cultivars suitable for growing under integrated systems.
Rubus breeding: *Phytophthora* resistance

The development of cultivars with resistance to raspberry root rot caused by the fungus, *Phytophthora fragariae* var. *rubi*, is of paramount importance. This is the most destructive disease to affect raspberries in Scotland, accounting for 20% of the tonnage lost. At present, the few existing resistant cultivars lack acceptable fruit quality or yield.

Currently, a full 25% of the crossing programme is entirely dedicated to targeting resistance to the disease. Breeding for resistance was initiated in 1993, incorporating resistance genes from local wild populations and later from breeding material from the Pacific Northwest and Norwegian programmes.

Progeny from these crosses are screened in an infestation plot and evaluated when the controls are dead/showing symptoms. Currently 35 putative resistant genotypes have been identified. These are propagated and planted into replicated 5-plant plots in both infected and healthy plots for further evaluation on fruit quality.

Development of molecular markers linked to *Phytophthora* resistance

In addition to the breeding programme, SCRI pursues a fundamental science programme, funded by the Scottish Executive, to underpin and complement the breeding work. Part of this programme aims to develop molecular markers for *Phytophthora* resistance.

A population segregating for *Phytophthora* resistance was created using the cross, ‘Glen Moy’ x ‘Latham’ (derived from *R. strigosus*). The progeny were screened for 3 years in infested field plots and segregated into resistant, moderately resistant and susceptible bulks. Using bulk segregant analysis, RAPD bands were found to be present in the resistant and moderately resistant progeny but absent from the susceptible progeny.

Marker-assisted selection will be a useful tool in future breeding strategies for *Phytophthora* resistance as it will enable more rapid identification of resistant genotypes. Field infestation plots show results only after several years and glasshouse screening has to date shown no correlation to field results.

Rubus breeding: Aphid resistance

For more than 30 years virus diseases transmitted by the large raspberry aphid *Amphorophora idaei* have successfully been managed by growing resistant raspberry cultivars containing the genes A1 or have minor gene resistance, e.g., Glen Ample, Glen Prosen and Glen Moy (A1) and Glen Clova (minor gene). Recently the aphids have succeeded in overcoming these sources of resistance and now most of the effort has been to breed raspberries containing gene A10 from the American black raspberry (*R. occidentalis*). As a result, more than 90% of the progeny from the most recent breeding programme (1996 onwards) carry this gene that confers resistance to four biotypes of the aphid vector. However, with the increase in material containing this gene, there is growing evidence that, particularly in southern England, aphids are able to colonise cultivars containing A10. In view of this we have started to screen for novel sources of resistance from both wild *Rubus* and related species.

Other key pests and pathogens of raspberries

*Raspberry Beetle (Byturus tomentosus)*

Raspberry beetle remains one of the most important pests of raspberry and control usually involves one or two carefully-timed applications of insecticide; the first, applied just before the first flowers open to kill the adults before they oviposit, and the second in the interval between 80% petal fall and the first pink fruit stage to kill the eggs and larvae (Taylor and
Application of insecticides in the period close to fruit harvest is now becoming increasingly unacceptable because of the potential risk of residues in the fruit (Jennings, 1988). Currently there are no specific breeding strategies for control. However, over the years various *Rubus* species and hybrids have been investigated as possible sources of resistance. *R. phoenicolasius*, *R. coreanus*, *R. crataegifolius* and their derivatives and the purple raspberry cv. Glen Coe have all shown some levels of resistance to larval damage (S.C. Gordon, unpublished data).

*Raspberry Cane Midge (Resseliella theobaldi)*

Feeding damage caused by raspberry cane midge larvae predisposes raspberry canes to the disease known as 'midge blight' which is responsible for major losses in raspberry in many parts of Europe (Woodford and Gordon, 1978). Raspberry cane midge over winter in cocoons in the soil at the base of raspberry canes and pupate shortly before they emerge. Eggs are laid in splits and wounds in the bark at the base of the young canes and the larvae feed in the outer cortical tissue protected by the covering of bark. Second and subsequent generations follow during the summer and early autumn. The second generation is usually the largest because fresh natural splits are then abundant in the rind of the rapidly growing primocanes providing the first generation females with plentiful oviposition sites. Midge larval feeding sites become infected by a range of fungi that lead to cane death during the winter. Raspberry cane midge can also be controlled by cultural methods to eliminate oviposition sites, e.g. use of desiccant herbicides in the spring removes the first flush of vegetative canes of vigorous cultivars. This treatment results in replacement canes that are free from splits during the period of first generation midge egg laying. The raspberry cultivar 'Glen Prosen', and the hybrid berries Tayberry and Loganberry, do not readily split their rind in the spring, and are rarely affected by 'midge blight'. Other *Rubus* species and crosses have been investigated as sources of resistance to raspberry cane midge. *R. parvifolius*, *R. odoratus* and F2 crosses of *R. crataegifolius* x *R. idaeus* were found to be resistant when exposed to raspberry cane midges (McNicol et al., 1983). Although selection for smooth rind is not a high priority, cultivars showing this characteristic will be considered for selection for IPM production.

*Raspberry Bushy Dwarf Virus*

One of the main viral threats to raspberry production in Europe is the spread of raspberry bushy dwarf virus (RBDV). This pollen borne virus is widespread in raspberry and is difficult to control. Cultivars with resistance genes to common isolates of this virus are effective in preventing infection but the occurrence of resistance-breaking isolates (RB) pose serious problems for future control (see Jones – this volume). In our breeding programme resistant selections of raspberry from breeding programmes in the Pacific North West of USA have been crossed with SCRI material. The resultant crosses will be screened for resistance.

**The Future of Scottish Raspberries**

In recent years the soft fruit industry in the UK has increasingly focussed its attention on the production of crops under protection for the fresh market. Strawberry production has increased as a result; fresh raspberry production appears to be following in this direction. The advantages of protected cropping systems include season extension and improvement of fruit quality. Care is required in the selection of cultivars for use in these systems: for example, such changes in agronomic practices have implications for a shift in pest and pathogen pressures. The long cane production system provides an opportunity for selection of genotypes with a low chilling requirement, and a shorter flower to fruiting period.
Commercial funding between 1993 and 2000 saw the breeding programme focus upon the development of machine harvestable cultivars for processing. However, it is the fresh market sector that represents the main area for potential growth in both field and season extension contexts. The programme at SCRI is addressing these needs within the broad base of *Rubus* germplasm available and selection procedures for these and many other traits is possible.

**Ribes breeding**

*Blackcurrant gall mite (Cecidophyopsis ribis)*

Blackcurrant gall mite is the most important pest of cultivated blackcurrants in Europe, New Zealand and Tasmania. Apart from causing direct damage to infested plants by causing galls that fail to develop into shoots and have no flower initials, they are the sole vector of blackcurrant reversion virus. Good control of the mites by chemical means is becoming increasingly difficult with the withdrawal of many of the more effective products due to environmental and toxicological concerns. As a consequence, breeding of resistant blackcurrants, with good agronomic features has been of high priority.

Several sources of resistance have been investigated, however, the most effective has been the *Ce* gene, derived from gooseberry (Knight et al., 1974). Incorporation of this gene into agronomically acceptable cultivars has taken several generations of extensive back-crossing and selection. Selection had previously relied heavily on exposure of progeny to heavy mite pressure in isolated infestation plots with selections exposed for up to three years to ensure that the resistance was robust (Brennan, 1996).

AFLP markers linked to the *Ce* gene for gall mite resistance have recently been identified (Brennan, 2002), and appropriate deployment strategies for this and other molecular markers (mainly SSRs) currently under development will accelerate the identification and eventual release of new resistant hybrids. However, diversification of the pest and disease resistance donors is essential for the future success of the SCRI Ribes programme. The resistant cultivar ‘Ben Hope’ was released in 1999 from SCRI, and provides the industry with high productivity and fruit quality allied to mite resistance. The most recent evidence has shown that the resistance may not be complete, and further work and incorporation of alternative resistance genes is required in the future.

*Blackcurrant reversion virus*

Blackcurrant reversion virus, in association with its vector, blackcurrant gall mite, present one of the most serious disease threats to blackcurrant worldwide (see Jones – this volume). Chemical control is becoming more difficult and when 5% of plants are galled further chemical control becomes uneconomic. Breeding for resistance to blackcurrant reversion virus is now a major priority (Brennan, 1990; Brennan et al., 1993). Resistance has been identified in *R. cereum*, *R. dikushka* and *R. pauciflorum*, and a resistant cultivar, ‘Ben Gairn’ was released from SCRI in 1999. Resistance in this cultivar is derived from the Russian cultivar ‘Golubka’, itself a derivative of *R. dikushka*. Further resistant cultivars should be more readily available with the development of a rapid PCR-based diagnostic test for reversion virus (A.T. Jones, pers. commun.). Such tests will supersede the existing very protracted grafting procedure.

*Blackcurrant leaf midge (Dasineura tetensi)*

Blackcurrant leaf midge remains a major pest of blackcurrant in many parts of Europe. Recent research in the UK (Crook et al., 2001) has shown that the SCRI-bred cultivar Ben Connan is
resistant to larval feeding, although adult midges do lay eggs. Although this insect is not screened on a regular basis, plants showing field resistance are selected when suitably high levels of infestation are found. However, in commercial blackcurrant production, the use of synthetic pyrethroid insecticides for blackcurrant gall mite control has also reduced the incidence of leaf midge. The imminent withdrawal of these chemicals from the blackcurrant pest control portfolio will inevitably lead to an upsurge in the importance of this pest, so the introgression of new sources of resistance, such as \textit{R. americanum} and \textit{R. dikuscha} (Keep, 1985), will become a priority.

**Discussion**

The most recently released cultivars of both \textit{Rubus} and \textit{Ribes} from the SCRI and Mylnefield Research Services programmes offer significant advances in both agronomic and fruit quality traits, including pest and disease resistance. However, there is clear evidence that further work is required, particularly in the areas of resistance to root rot and aphids in \textit{Rubus}, and in gall mite and leaf curling midge in \textit{Ribes}. To achieve these objectives, the use of new marker-assisted screening protocols, together with the incorporation of hitherto under exploited germplasm, is likely to have a pivotal role in the future, particularly in the present climate of reducing chemical inputs and increased use of ICM programmes.

**Acknowledgements**

Financial support for this work from the Scottish Executive Environment and Rural Affairs Department, Scottish Soft Fruit Growers Ltd. (\textit{Rubus} breeding) and Glaxo SmithKline Consumer Healthcare (\textit{Ribes} breeding) is gratefully acknowledged.

**References**


"Minor" uses in soft fruit crop protection in Germany

Peter Galli 1, Lutz Gündel 2, Erich Jörg 2, Uwe Harzer 3
1 Landesanstalt für Pflanzenschutz, Reinsburgstr. 107, 70197 Stuttgart, Germany
2 Landesanstalt für Pflanzenbau und Pflanzenschutz, Essenheimerstr. 144, 55128 Mainz, Germany
3 Staatliche Lehr- und Forschungsanstalt für Landwirtschaft, Weinbau und Gartenbau, Breitenweg 71, 67425 Neustadt/Wstr., Germany

Abstract: For German soft fruit production plant protection product (p.p.p.) availability is insufficient, both in quantity and quality. This due to the high requirements for p.p.p.-registration and the lack of interest by chemical industry to register p.p.p. in minor and very minor crops. In order to supply the fruit growers with p.p.p.s, registration authorities and the governmental crop protection services have installed a working group "Minor Uses" and an approval procedure to permit the use of registered p.p.p.s in other fields of application than mentioned in the registration. The governmental crop protection services devote considerable labour capacity and funding for residue analyses to this approval procedure. Recently in Germany more p.p.p.s are approved than registered by the normal registration procedure for soft fruit crop protection.

An international co-operation, including exchange of trial and residue analyses results and a co-ordinated planning of "minor uses"-trials, would be very helpful in providing soft fruit growers with p.p.p.s suitable for Integrated Production.

Keywords: Soft fruit crops, plant protection products, minor uses, off-label registration

Plant protection product availability in soft fruit crops

Until 1998 plant protection product (p.p.p.) availability in arable and horticultural crops in Germany has not been problematic. In 1998 a new Plant Protection Act has been enforced and as a consequence the number of p.p.p.s which may be applied in minor or very minor crops has dropped dramatically. This holds for fruit, vegetable, ornamental and herbal crops as well as for some arable crops. In total about 410 different crops are commercially grown in Germany. Most of them (380) are considered to be either minor or very minor crops (see Fig. 1). Total agriculturally used area comprises of 12.01 million hectares of which 2.3 %, i.e. approximately 280,000 ha, are cropped with minor or very minor crops (Fig. 1). Crops are classified as "minor" or "very minor" according to their daily dietary intake contribution, cropping area and annual production (Table 1).

Table 1. Significance of Crops (CEC 1999)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Major crop</th>
<th>Minor crop</th>
<th>Very minor crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily dietary intake</td>
<td>&gt; 7.5 g</td>
<td>7.5 g – 1.5 g</td>
<td>&lt; 1.5 g</td>
</tr>
<tr>
<td>contribution</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cultivation area</td>
<td>&gt; 10 000 ha</td>
<td>10 000 – 600 ha</td>
<td>&lt; 600 ha</td>
</tr>
<tr>
<td>Annual production</td>
<td>&gt; 200 000 t/y</td>
<td>&lt; 200 000 t/y</td>
<td>-</td>
</tr>
</tbody>
</table>
In Germany all soft fruit crops are of minor or very minor importance according to CEC (1999). In most of the crops many pests, diseases or weeds can not be controlled due to a lack of registered p.p.p.s. For soft fruits a total of 55 significant gaps in the fields of applications has been defined for which no product is available (Fig. 2). Mainly fungicides and herbicides are lacking, and the situation is worst for crops with a complex biological constraint system (many pests and fungal diseases), i.e. raspberries and currants (Fig. 2).

Figure 1. Significance of crops in Germany and growing area in 2000

Figure 2. Significant gaps in fields of application in soft fruit crops in Germany in 2001
Most products are registered for strawberries (22), followed by gooseberries (11) and currants and raspberries (10). For blackberries, elderberries and blueberries only 5 and 4 products respectively are available (Tab. 2). Active ingredients (a.i.) with quite poor efficacy, as e.g. potassium soap, pyrethrum or mineral oil, are included into the overview given in Tab. 2. On the other hand non-selective a.i.s (pyrethroids) sometimes are the only effective products registered for pest control. For most of the fields of application only one a.i. is registered. Thus an effective anti-resistance management for insect-, mite- and fungal disease-control is impossible. Integrated plant protection in soft fruit crops is far from meeting the standards that have been introduced into pome or stone fruit IP.

Table 2. Plant Protection Products registered for the Use in Soft Fruit Crops in Germany -Products / active ingredients (Status: Sept. 2001)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Insectic.</td>
<td>4 / 4*</td>
<td>4 / 2**</td>
<td>6 / 4**</td>
<td>6 / 4**</td>
<td>3 / 1**</td>
<td>4 / 2**</td>
<td></td>
</tr>
<tr>
<td>Acaric.</td>
<td>1 / 1</td>
<td>0 / 0</td>
<td>1 / 1**</td>
<td>0 / 0</td>
<td>1 / 1**</td>
<td>0 / 0</td>
<td></td>
</tr>
<tr>
<td>Fungic.</td>
<td>8 / 9</td>
<td>2 / 2</td>
<td>2 / 2</td>
<td>2 / 2</td>
<td>2 / 2</td>
<td>1 / 1</td>
<td></td>
</tr>
<tr>
<td>Herbic.</td>
<td>6 / 4*</td>
<td>4 / 4</td>
<td>0 / 0</td>
<td>1 / 1</td>
<td>1 / 1</td>
<td>0 / 0</td>
<td></td>
</tr>
<tr>
<td>Mollusc.</td>
<td>3 / 2</td>
<td>0 / 0</td>
<td>0 / 0</td>
<td>1 / 1</td>
<td>0 / 0</td>
<td>0 / 0</td>
<td></td>
</tr>
</tbody>
</table>

* = incl. Glufosinate for runner control
** = incl. mineral oil
* = incl. Potassium soap
** = incl. Pyrethrum

Legal basis of plant protection product availability

Up to 1998 registration of p.p.p., as it was laid down in the German Plant Protection Act of 15 September 1986, aimed at regulating the marketing of p.p.p.s. Only registered products could be used in crop protection. In the Act the application of p.p.p. was not further restricted. Once a product was registered it could be applied in all crops provided that two ordinances, the Plant Protection Use Ordinance (PPU-O, 1992) and the Residue Maximum Amount Ordinance (RMA-O, 1989), were not violated. In PPU-O. the use of certain a.i.s was explicitly forbidden (e.g. DDT, Atrazine...), banned in ground water protection zones (a.i.s with high leaching ability) or restricted to a certain crop or pest or disease. If residue analyses revealed that the application of an a.i. in a certain crop did not lead to higher residues than specified in RMA-O. the use was permitted. With respect to the high costs of the registration process in Germany chemical companies did not register many a.i.s in minor or very minor crops.

In 1998 the German Plant Protection Act was adapted to EU plant protection legislation. Now the Act strongly regulated the application of p.p.p.s. Registration specified the crop, noxious organism and often time of application, i.e. "the field of application = indication" for the product. Only in the defined fields of applications the products are permitted (Table 3, § 15). Often further restrictions were imposed (e.g. maximum number of applications or safety distances to water courses). After a transition period which ended in June 2001 the use of p.p.p.s in non-registered fields of applications was prohibited.
Table 3. Registration and Approval as defined in the German Plant Protection Act (14 May 1998)

<table>
<thead>
<tr>
<th>§ 15 Registration (normal procedure)</th>
</tr>
</thead>
<tbody>
<tr>
<td>♦ application for registration with a complete data set (ref. § 12 ....)</td>
</tr>
<tr>
<td>♦ a.i. of the p.p.p. is listed in Annex I EU-Guideline 91/414</td>
</tr>
<tr>
<td>♦ after tests confirm efficacy, no non-tolerable phytotoxicity, no hazardous effects on health of humans and animals and ground water, no other non-tolerable effects on nature....</td>
</tr>
<tr>
<td>♦ maximum residue levels must be determined</td>
</tr>
</tbody>
</table>

15 (2) BBA decides on field of application, limits, restrictions in application, persons who are permitted to use p.p.p.

15 (3) BBA decides in accordance with federal environmental and health agency

§ 15b Registration of p.p.p. which are registered in other EU countries
yes, if requirements of EU-Guideline 91/414 fulfilled and a.i. in Annex I; but limitations of use or refusal of registration are possible

§ 18 Approval
Permission to use p.p.p. in other fields of application (crops, noxious agents) than mentioned in the registration, if
♦ public interest,
♦ requirements of registration are fulfilled,
♦ crops are grown on a limited production area,
♦ pests occur only occasionally or in certain regions and cause severe damage,
♦ if they are applied in insignificant amounts.

Approval in accordance with federal environmental and health agency.

§ 18a Approval procedure
§ 18a (1): who can apply for an approval?
♦ owner of registration, users of p.p.p. in agricultural, horticultural and forestial enterprises, governmental and scientific institutions in agriculture, horticulture and forestry.

§ 18a (2): Owner of registration has to be consulted (check whether a potential objection to the approval is justified or not).

§ 18a (3): Approval in accordance with federal environmental and health agency.

§ 18a (4): Approval / withdrawal of approval becomes valid after publication in the Federal Law Gazette.

§ 18b Approval for individual cases
"Responsible authority" (GCPS of the German Bundesländer) may approve the use of a registered p.p.p. in other fields of application than mentioned in the registration,
♦ in very minor crops,
♦ against severely damaging noxious agents which only occur regionally/locally.
♦ limited period.
(Recent procedure: Only if agreed by BBA (registration authority).

In § 18 (a, b) of the Plant Protection Act an approval of p.p.p.s for special uses is mentioned which enables the registration authority in charge (BBA) to permit the application in non-registered fields of application.
Approval procedure of "Minor Uses" in Germany

Based on § 18 of the German Plant Protection Act a working group "Minor Uses" was established consisting of members of the responsible registration authority (BBA) and the GCPS. The working group is divided into six subgroups for the various groups of crops (arable crops, fruits, vegetables, ornamentals, herbal crops and viticulture).

The working group has developed a procedure for approving p.p.p. for the use mainly in minor and very minor crops or insignificant fields of application (Figure 3). BBA defines the gaps in fields of applications, pre-judges the given proposals for minor uses and checks the possibility of extrapolations of p.p.p. uses in negotiations with the joint - registration authorities. The GCPS elaborate the proposals for minor uses, conduct efficacy and phytotoxicity trials and organise the funding for the required residue analyses.

A - Role of BBA

<table>
<thead>
<tr>
<th>Identification/definition of gaps</th>
<th>- in co-operation with GCPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-judgement of application</td>
<td>- in co-operation with registration authorities</td>
</tr>
<tr>
<td>Possibility of extrapolations</td>
<td>- in co-operation with registration authorities</td>
</tr>
<tr>
<td>Approval according to §18a</td>
<td>- in co-operation with registration authorities</td>
</tr>
</tbody>
</table>

B - Role of GCPS

<table>
<thead>
<tr>
<th>Proposal for an application</th>
<th>- in co-operation with GCPS and agrochemical industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficacy trials</td>
<td>- uniform design, assessments, analyses, reports</td>
</tr>
<tr>
<td></td>
<td>- phytotoxicity assessments</td>
</tr>
<tr>
<td>Residue analyses</td>
<td>- conduction of the field trials, sampling</td>
</tr>
<tr>
<td></td>
<td>- analyses in GLP- laboratories</td>
</tr>
<tr>
<td></td>
<td>- administration and organisation of financiation for residue analyses</td>
</tr>
</tbody>
</table>

Residue analyses requirements for "Minor Uses":
- minor crops: 4 analyses (2 residue decline studies / 2 residue values)
- very minor crops: 4 analyses (4 residue values)
- major crops: 8 analyses (4 residue decline studies / 4 residue values)

Figure 3. Approval procedure for "Minor Uses" in Germany. Work from 1996 – 2001
The approval procedure just simplifies the registration procedure whilst maintaining the high protection level of consumers, users of p.p.s, abiotic environmental resources and nature.

GCPS devote a considerable share of their trial capacity towards the minor uses procedures. From 1996 to 2000 more than 300 trials have been laid out in soft fruit crops by the "Minor Uses" - subgroup "Fruit Crops". Main emphasis was on fungicide and herbicide trials (Fig. 4). By far the most trials were done in strawberries followed by raspberries (Table 4). Twenty to thirty trials were conducted in currant and gooseberry crops. The least number of trials were laid out in blackberry, elderberry and hazelnut. The most intensive years were 1997 to 1999.

Table 4. Working Group "Minor Uses/ Subgroup Fruit Crops". – No. of trials in soft fruit crops 1996 - 2000

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Strawberry</td>
<td>2</td>
<td>26</td>
<td>30</td>
<td>24</td>
<td>18</td>
<td>100</td>
</tr>
<tr>
<td>Raspberry</td>
<td>8</td>
<td>12</td>
<td>22</td>
<td>16</td>
<td>11</td>
<td>69</td>
</tr>
<tr>
<td>Blackberry</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>Currants</td>
<td>1</td>
<td>14</td>
<td>10</td>
<td>3</td>
<td>1</td>
<td>29</td>
</tr>
<tr>
<td>Gooseberry</td>
<td>0</td>
<td>9</td>
<td>7</td>
<td>4</td>
<td>3</td>
<td>23</td>
</tr>
<tr>
<td>Blueberry</td>
<td>0</td>
<td>1</td>
<td>9</td>
<td>10</td>
<td>7</td>
<td>27</td>
</tr>
<tr>
<td>Elderberry</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>Hazelnut</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>13</td>
<td>72</td>
<td>90</td>
<td>65</td>
<td>41</td>
<td>321</td>
</tr>
</tbody>
</table>

Figure 4. Working Group "Minor Uses / Subgroup Fruit Crops" Number of trials in per pesticide group 1996 - 2000
Table 5. Minor Uses trials in soft fruit crops in Germany - Fields of application (programme 2000/2001)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Acaricides</th>
<th>Insecticides</th>
<th>Fungicides</th>
<th>Herbicides</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Appl. 1</td>
<td>P.p.p. 2</td>
<td>Appl. 1</td>
<td>P.p.p. 2</td>
<td>Appl. 1</td>
</tr>
<tr>
<td>Strawb.</td>
<td>16</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>Raspb.</td>
<td>4</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Blackb.</td>
<td>4</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Currants</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Gooseb.</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Blueb.</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Elderb.</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Sum appl.</td>
<td>32</td>
<td>5</td>
<td>32</td>
<td>28</td>
<td>97</td>
</tr>
</tbody>
</table>

1 = field of application; 2 = plant protection product

The trials deal with all relevant pest, disease and weed problems in German soft fruit production. (Table 5). In addition a comprehensive residue analysis programme is carried out which focuses on a.i.s of acaricides, fungicides and herbicides both in open field and protected production.

Table 6. Applications for Approval of P.P.P. in Soft Fruit Crops (acc. to § 18a, 8/2001)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Acaricides</th>
<th>Insecticides</th>
<th>Fungicides</th>
<th>Herbicides</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Appl. 1</td>
<td>P.p.p. 2</td>
<td>Appl. 1</td>
<td>P.p.p. 2</td>
<td>Appl. 1</td>
</tr>
<tr>
<td>Strawb.</td>
<td>16</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>Raspb.</td>
<td>4</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Blackb.</td>
<td>4</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Currants</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Gooseb.</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Blueb.</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Elderb.</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Sum appl.</td>
<td>32</td>
<td>5</td>
<td>32</td>
<td>28</td>
<td>97</td>
</tr>
</tbody>
</table>

Until the beginning of September 2001 GCPS applied for about 100 approvals (fields of applications) in soft fruit crops (Table 6). One third was for strawberries and ca. 10 per cane or bush fruit crop or elderberry. Most approvals were submitted for acaricides and fungicides followed by herbicides. "Minor Uses - applications" by the GCPS were quite successful. By normal registration procedure (acc. to § 15; see Tab. 3) 7 p.p.p.s were registered in a total of 11 fields of application for soft fruit crops in 2000 and 2001. In the same period 6 p.p.p.s and
24 fields of applications were approved according to § 18a. Approvals have become more important than registrations with respect to the supply of soft fruit growers with p.p.p.s.

Despite the success many obstacles hinder or slow down the approval process for minor uses. Fusions of companies in agro-chemical industry strongly influences registration activities. Often the newly founded company loses interest in certain a.i.s which no longer are kept registered. Due to the high requirements for inclusion of a.i.s into Annex I of EU-regulation 414/91 companies renounce on the re-registration of a.i.s. It is expected that in 2003 from 800 registered a.i.s only 225 will be kept. Both facts will lead to a loss of potential a.i.s for minor uses. Fixation of maximum residue levels takes two years. This long time span often postpones the approval procedure because an approval only can be given if maximum residues for a.i - crop combinations are laid down. In addition it is very difficult to get residue analyses funded, a further complication for approval. Due to the severe restrictions in defining fields of application by some registration authorities (see Table 3), partly they are pest - specific within a larger group of similar pests, the number of gaps slowly increases over time.

**Proposal: How to proceed further by international co-operation**

The situation for soft fruit p.p.p.s seems to be the same in many European countries (see Jörg and Gajek, this volume). An international co-operation would be very helpful in facilitating the approval of p.p.ps for minor uses for soft fruit crops in Europe. A concerted action could speed up the approval process, save trial capacities and money and maybe encourage agro-chemical companies (which anyway act on the international level) to register more p.p.p.s in soft fruit crops. More emphasis could be given to the quality of a.i.s with respect to suitability for IP than it is done up to now:

A first step could be the exchange of information on national registration and approved minor uses. The installation of a databank containing these information and in addition information on the availability of efficacy and phytotoxicity trial results or residue decline studies and residue values at harvest would be extremely useful. As a next step co-operation on the exchange of data obtained by observing GLP or GEP standards could be started. These co-operations could end up in installing a small steering committee which organises the joint planning of minor uses approvals and the joint working out of the data packages needed.

**References**

CEC. 1999: Doc.7525/VI/95-rev.5 Working Document: "Guidelines on comparability, extrapolation, group tolerances and data requirements for setting MRLs".


Open Forum: discussion on effect of changing pesticide usage and availability on soft fruit pest and disease management

Discussion Leader: Roger Umpelby  
ADAS Rosemaund, Preston Wynne, Hereford HR1 3PG, UK

Abstract: The discussion covered all aspects of the impact on soft fruit growers of the availability and registration of pesticides in different member countries. The variations in availability and of restrictions on the usage of pesticides in different countries were highlighted. Particular concern was expressed about the limited choice of pesticides for some problems with the increased risk of resistance selection. For some pests and diseases in some countries, only broad-spectrum pesticides are available, making integration into an ICM system difficult, or even impossible. An outline proposed collaboration between member countries to share and exchange information was agreed.

Key words: Registration, approval, pesticides, Integrated Crop Management, ICM, Integrated Pest and Disease Management, diseases, pests

Introduction and background

Formal Approval systems for Integrated Crop Management (ICM) differ in different member countries of the EU. There is a perceived unfairness with non-uniformity of approval status of chemicals, including the Off-label chemicals (e.g. most UK Off-label approvals are not pest or disease specific). In the UK, these products are approved under the ‘Specific Off-label Approvals (SOLA)’ regulations.

There are sometimes additional imposed restrictions on use of Approved pesticides in some countries, either by governments, or by the grower’s customers. Because of concerns about pesticides contaminating surface water channels, 'buffer zones' are strictly imposed and the size of these buffer zones varies greatly – they may even extend to the size of a whole field. Major buyers, such as supermarkets and processors, may impose restrictions well above the terms of Registration, e.g. prohibiting the use of certain pesticides or setting Maximum Residue Limits (MRLs) well below official levels.

Approval does not mean proven (for Off-label) or continuing (for On-label) efficacy against a particular target pest/disease/weed. Pesticides often continue to be approved even after the target organism has become resistant to it. All Approvals do however relate primarily to toxicology, chemical residues analysis reports and the likely environmental impact of use of a particular chemical.

There is an apparent inconsistency in the use of terms defining the spectrum of activity of a given pesticide – what does 'broad-spectrum' mean when applied to insecticides and fungicides?

Registration of pesticides in different countries is uneven in its requirement to specify the likely impact of a chemical on 'beneficials', e.g. UK registrations must include these data, but only on certain types of beneficials, other countries have different requirements and may use a different range of beneficials.

Over-use of a chemical can lead to an increased risk of resistance in a pest/pathogen to that particular chemical, and sometimes one or more class of chemical. The over-use of pesticides by propagators and plant raisers is of particular concern because any resistant pest
or disease population present will be carried directly into commercial production crops. The increasing international trade in plants means that spread of resistant organisms may be extremely extensive. This matter is particularly pertinent following the introduction of Plant Passports in Europe, a system that has demonstrably failed to exclude important pathogens/pests from member countries!

The pesticide Approval schemes in various countries differ in their specifications for chemicals to be used in open field or protected cropping (under plastic or glass), for example there is a different approach to this issue in Germany compared to the UK.

New pesticide approvals for 'minor crops', such as soft fruits, are becoming fewer, mainly due to the cost of pesticide development, but at least in part due the cost of registration. Compounding the pesticide availability problem for minor crops is the on-going re-evaluation of older Approved chemicals which is designed to ensure that the highest standards are maintained in terms of toxicological and environmental aspects. This re-evaluation is expensive and manufacturers may withdraw pesticides because the additional work needed is uneconomic. The definition of 'minor crop' status also differs in different agrochemical companies and even in different countries.

Harmonisation of pesticide registration methods across European countries is important, especially for minor crops, because individual governments can, at least in theory, still protect their own national interests by excluding a particular chemical, although this decision must be justified.

Apart from the loss of Approved pesticides by the withdrawal or loss of Approval, reductions in MRLs, sometimes at the limit of detection, can effectively mean growers cannot use certain Approved products thereby further reducing their choice of pesticides. This problem particularly affects long-Approved pesticides, because analytical techniques have advanced and much lower residues can be detected now than when the pesticide was first introduced.

Discussion

Buffer zones
Erich Jörg (Germany) explained that Germany has buffer zones up to 150 m wide for some insecticides and there are whole regions in northern districts where chemicals cannot be used because of their proximity to surface waterways. Other specifications are very restrictive for growers because they stipulate that a particular chemical may only be applied before or after a given date. Christer Torneus (Sweden) said that in his country buffer zones were not specified on the Approved Label, but certification of spray operators includes training on correct practices that would cover this aspect. R. Olszak (Poland) commented that buffer zones are only applied for particular pests; even if not specified on the Label, buffer zones are covered by laws. Dany Bylemans said that the Belgian Government does not accept buffer zones to control pesticide use because many farms in Belgium are very small (less than width of zone!) and instead they will choose to stop the registration of a new chemical (or severely restrict its use) without giving consideration to the many farms that are not beside water courses. As a result of this policy there are no insecticides available to soft fruit growers.

Erich Jörg said that there is also a system in Germany that can modify the width of buffer zones by specifying certain spray nozzles or spray equipment. [Nozzle/sprayer specifications were described by Holger Daugaard (Denmark) in his paper about grey mould control in strawberry.] Roger Umpelby pointed out that beneficial organisms mainly come from hedgerows and field-margins, not the surface water, and that in an ICM system this habitat
also needed protecting. Jerry Cross (UK) suggested that permanent habitat zones are needed to foster natural populations of beneficial organisms.

**Broad-spectrum versus specificity**

Dany Bylemans explained that agrochemical companies are trying to place information on Labels about protection of beneficials, but that in Belgium they cannot place the information on the Label unless there is testable scientific evidence. Farmers now need to check the Label because 'IPM status' no longer applies in Belgium. Roger Umpelby said that manufacturers would probably wish to promote broad-spectrum materials that inherently have a wider market thus increasing the returns on development investment. David Northcroft (UK) explained that in the UK for some soft fruit pests the only Approved products are broad-spectrum ones toxic to predators introduced for control of mite and aphid pests. Angela Berrie (UK) commented that if broad-spectrum materials are replaced with specific materials the increase in the number of separate applications and of different pesticides may ultimately be too expensive. Dany Bylemans commented that when too many specific chemicals are applied, it leads to rapid resistance build-up in populations. Roger Umpelby stressed that the special problem with most soft fruit crops is that they are perennial plants with a long plantation life which allows pest/pathogen populations to build-up over a long period. As a consequence there is a much wider range of pest and disease problems in these crops compared to annual arable and vegetable crops.

Nina Trandem (Norway) asked whether all the possible pests controlled by a particular product are specified on the Approved Label, or only those for which it was Approved? Roger Umpelby explained that in the UK the product Label (Full-approval) must give the target organisms, but may include a statement that the product 'will give suppression of' other named targets. Erich Jörg said that Germany uses the same approach, except that statements of this kind would be made in product information leaflets, rather than on the Label. However, for Norway, Nina Trandem said that the registration authority wishes to restrict the use of certain chemicals against a pest on a single crop to stop wider use of the material. Jerry Cross explained that in the UK the Off-Label status could only be sought for a chemical already Approved for use in that country on some other crop. Roger Umpelby said that broad-spectrum insecticides should not be considered as part of on ICM programme, and it was important to classify chemicals on their relative persistence in the environment. Dany Bylemans pointed out that broad-spectrum pesticides, providing they were not persistent, could be used to reduce the size of a pest population before introducing predators. Jerry Cross suggested that an intermediate status in the spectrum of activity of a chemical was needed. Stuart Gordon (UK) said that he agreed that there was a place for broad-spectrum materials in an ICM programme, especially for materials with a very 'short life'. He asked whether we should make a case for such a use to be deployed as a 'clean-up' before introduction of predators.

Trefor Woodford (UK) commented that some consideration should be given to the location in the crop canopy where a pest resides or a disease attacks. For example, fenitrothion (no longer Approved) and chlorpyrifos were used in a high-volume application directed to the cane bases to control raspberry cane midge in the UK to reduce the risk of spraying the upper part of the canopy near blossom time when bees would be affected.

Christer Torneus said that day-degree models could lead to lower dose rates and a narrower spray window to protect beneficial insects, particularly those valued for control of certain pests.
Registration costs
Jerry Cross asked whether we could load the registration cost for minor crops on to arable crops to provide a subsidy to the former. At present there is no incentive for companies to register chemicals for minor crops. Erich Jörg said that the problem was that the soft fruit industry does not have enough chemicals from which to choose because of high registration costs. Trefor Woodford asked how many countries in the EU had an Off-Label scheme for chemicals? He said that the Central Science Laboratory (CSL), York, UK has an on-line database called 'LIAISON'; are similar databases accessible elsewhere in Europe?

Discussion on proposals
Jerry Cross commented that a EU 'Minor Uses Working Group' has been established by Registration Authorities. Roger Umpelby suggested an expansion of this base to specify ICM compatibility of chemicals. Erich Jörg stated that an overview of the status of chemicals across Europe was still lacking, but Jerry Cross commented that this would be difficult to achieve because Approved minor uses changed monthly. Nevertheless, Erich Jörg said that crop advisers should have information about the registration of chemicals and their uses in other countries so that they can apply for Approval in other countries.

The question of who would pay for Registration was raised. It was considered that levy boards and growers with larger cropping areas may be prepared to financially support registration. However, most Governments were thought to be unlikely to support registration because their current polices are that such support should be the responsibility of growers.

Dany Bylemans asked whether we should try to divide the registration/approval work across Europe because most countries have too much work and too limited funds for this purpose? Christer Torneus suggested that we apply for EU funds to initiate such a database for soft fruit - IOBC could approach the Commission and present a project on soft fruit. Stuart Gordon (UK) asked whether we should approach the Commission under the CRAFT Scheme that involves Small-to-Medium-sized Enterprises (SMEs) with the objective of collating and consolidating this information? It could probably be done under the category 'Environmental Classification'. It was pointed out that a soft fruit group is already supported by the EU and Nina Trandem said that she would contact the latter group of which she is a member. Christer Torneus said that EPPO may have such an organisation, however, Dany Bylemans commented that, at least in Belgium, EPPO was not working in this area. Jerry Cross said that EPPO had a much wider responsibility than the European area, but we could ask EPPO to co-ordinate such an approach on our behalf. However, Roger Umpelby said that we needed to keep the focus of the IOBC Working Group.

Erich Jörg said that some members could start by creating a database and initiate collaboration. He said that only a small part of the total data set was missing and by collaboration these gaps could easily be filled by the IOBC Group. Nina Trandem suggested that before planning trials that members of this Working Group could be contacted by e-mail to avoid over-lap. Erich Jörg said that we should define a small collaboration to launch this approach. Roger Umpelby said that it was important to concentrate on chemicals that were effective, not just those that are Registered. The areas on which data was needed should be clearly defined, and we should not exclude biological control agents in this data acquisition.
Proposals for action by the Working Group

1. It was agreed that the Working Group was an ideal forum for co-ordination of information on usage and availability of pesticides for IOBC member countries.
2. Representatives from countries not represented at the meeting should be encouraged to participate in provision of information.
3. Members should collaborate by creating and maintaining a database specific to soft fruit, covering diseases, pests and weeds and their control. The database should cover pesticides (including availability, efficacy and ICM-compatibility) together with biological and other non-chemical control options.
4. Members should collaborate to seek EU-funding for joint projects, but also to explore funding from national sources.

Acknowledgements

Thanks are due to all participants at the meeting for their contributions to this discussion session.
Controlling raspberry beetle without insecticides

J.A.T. Woodford¹, A.N.E. Birch¹, S.C. Gordon¹, D.W. Griffiths¹, J.W. McNicol², G.W. Robertson¹
¹Scottish Crop Research Institute, Invergowrie, Dundee, DD2 5DA, Scotland, UK
²Biomathematics and Statistics Scotland, Scottish Crop Research Institute, Invergowrie, Dundee, DD2 5DA, Scotland, UK.

Abstract: Raspberry beetle (Byturus tomentosus) is a major pest of cultivated raspberries (Rubus idaeus) in Europe. In the absence of plant resistance or natural enemies, control depends on the application of insecticides close to flowering or harvest. A better understanding of the processes used by raspberry beetles for host recognition suggests that an alternative to insecticidal control is feasible. Adults use visual and olfactory cues to locate raspberry flowers in which they feed and mate. White sticky traps, which mimic floral spectral reflectance patterns, were shown to be effective for monitoring raspberry beetle flight activity. To avoid unnecessary insecticide use, control thresholds have been developed, based on relationships between numbers of trapped adult raspberry beetles and subsequent larval damage to fruit. Trap efficacy was highest when the beetles were active in warm weather before raspberries started to flower, and declined after flowering had started. Two components of the many volatile compounds emitted by raspberry flowers were selected in electrophysiological and behavioural studies. The addition of either of these volatile compounds to white sticky traps increased the numbers of raspberry beetles caught by the traps, and one of them increased the daily catch of raspberry beetles by 2-20 times in field tests, compared with the standard traps. In preliminary experiments to determine the effective trapping area, the volatile-enhanced traps caught marked beetles 5m from release sites. The potential use of volatile-enhanced white traps to "lure and kill" adult raspberry beetles is proposed as an alternative to insecticide control.

Key words: Raspberry beetle, Byturus tomentosus, kairomone, "lure and kill", trapping

Introduction

The raspberry beetle (Byturus tomentosus Degeer) is the most important pest of commercial red raspberry crops in the UK. Adults feed and mate in raspberry flowers, but the main damage is caused by larvae tunnelling into the developing fruit (Taylor and Gordon, 1975). Damaged fruit can be contaminated additionally by larval excreta and the entry of fungal pathogens (Woodford et al., 2002). Although sources of resistance to raspberry beetle have been found in some wild Rubus species (Briggs et al., 1982), no resistant raspberry cultivars are available. There is a very low tolerance for blemished fruit, and current control in commercial plantations depends on killing eggs and newly emerged larvae with insecticides, applied to the ripening fruit a few weeks before harvest (Gordon et al., 1997).

Raspberry beetles use visual and olfactory cues to locate raspberry flowers. Höhn (1991) tested a range of coloured sticky traps, and found that white, non-UV reflective traps were the most effective. Höhn et al. (1995) used these traps to avoid the need for routine applications of insecticides. They showed that the amount of damaged fruit in Swiss raspberry plantations was related to the number of adult beetles caught on sticky white traps, and suggested that control was unnecessary in plantations where low numbers of raspberry beetles were trapped. A recent EU project, ‘Reduced Application of Chemicals in European Raspberry Production’ (RACER), to develop IPM methods for raspberry producers (Gordon and Woodford, 2000), provided an opportunity to test the use of these traps for monitoring raspberry beetle activity,
and the results are summarised here. Birch et al. (1996) outlined multi-disciplinary studies at the Scottish Crop Research Institute (SCRI) which led to the identification of flower volatiles involved in host attraction and recognition by adult raspberry beetles. This paper describes how this knowledge of olfactory and visual cues for flower recognition has been combined to improve the efficiency of field traps, and the effects of their use to "lure and kill" adult raspberry beetles on subsequent larval damage to fruit.

Material and methods

Monitoring adult raspberry beetle activity
Raspberry beetle activity and flight periods were monitored in 1998 and 1999 in insecticide-free raspberry plantations in Switzerland (five sites), Scotland (five sites) and Finland (13 sites), as described by Woodford et al. (2000). Beetles were trapped on single plates of the white, non-UV reflective sticky cross traps (Rebell® bianco) that were used by Höhn et al. (1995). Four traps per site were changed at weekly intervals from 'first flower bud' stage until 'early green fruit' stage. The extent of fruit damage, assessed by recording the percentage of receptacles, tunnelled or infested by larvae, was compared with the mean numbers of raspberry beetles trapped before, and during, the flowering period (Woodford et al., 2000).

Testing chemical enhanced traps
A series of tests, outlined by Birch et al. (1996), were made to identify key plant chemicals that attract raspberry beetles to flowers. The approach combined automated thermal desorption (ATD)-gas chromatography (GC) - mass spectrometry (MS) to identify volatile compounds emitted from raspberry flowers (Robertson et al., 1993, 1994), and electrophysiology and behavioural studies in olfactometers and a wind tunnel to select promising candidate "attractant" compounds for testing in the field. Laboratory tests were made to standardise the release rates of these compounds from two types of lure, glass vials (08-CPV Chromacol) with a 1mm hole in the plastic lid, or pieces of cellulose sponge sealed in polyethylene sachets (Smart and Blight, 2000). In later tests, a cotton wick was inserted into the vial and cut flush with the top of the lid to increase the rate of release of one compound. Lures were attached to the Rebell® bianco sticky trap ('standard') in the field.

Experiments were made in a 1ha raspberry plantation at SCRI containing replicated plots of six cultivars. No insecticides were used in the plantation for four years and it was infested by large numbers of raspberry beetles. Traps were introduced for 3-4 days and records were made of the numbers of raspberry beetles caught each day. In 1999, two compounds were compared against a control (standard + empty vial) in four experiments, each with five replications. In 2000, two experiments were made to compare standard traps enhanced with one of the volatile compounds, using a vial or sachet release system. Information on the effective trapping area (Turchin and Odendaal, 1996) was obtained by releasing raspberry beetles marked with fluorescent powder (A7 Solar Yellow or A4 Flame Orange) at distances of 2.5m ('yellow' beetles) and 5m ('red' beetles) from the nearest trap. In 2001, three different types of trap (+ lure) were compared: standard, Vertical White sticky trap and green funnel trap (AgriSense-BCS Ltd.). The two types of white trap were then compared, each with and without the addition of lures. Each white trap type was replicated six times in two cultivars, cv. Glen Clova (early flowering) and cv. Glen Rosa (later flowering). Traps were positioned along rows, with a minimum separation of 2.5m between each trap. Two samples of 100 ripe fruits were harvested in early August from each row of cv. Glen Rosa that had contained traps, and from control rows, 5-7m distant. The percentage of fruit damaged by raspberry beetle larvae in samples from trap and control rows was compared using a Generalised Linear Model.
Results and discussion

Monitoring adult raspberry beetle activity

Raspberry beetles were trapped for at least 3wk before flowering started at each site. Maximum weekly catches were usually recorded before flowers opened in plantations in Scotland (Figure 1) and Finland, but there were large variations between sites and years and many beetles were trapped during the flowering period in Scotland and Switzerland. Insecticide sprays cannot be applied at this stage, when raspberry beetles lay their eggs in flowers, because of the risk to pollinators. Although an insecticide spray at 'green fruit' stage is still permitted in the UK, insecticide control is permitted only before flowering in many European countries. Monitoring would be most useful if the number of raspberry beetles trapped before flowering could be used to predict the extent of larval damage to fruit. However, a positive relationship between fruit damage and numbers of trapped raspberry beetles was rarely found for replicates within sites, and relationships between mean fruit damage and mean numbers of trapped raspberry beetles between sites were too variable to use the trap catches to predict damage (Woodford et al., 2000). For example, fruit damage at Scottish sites in 1998 was more closely related to the number of beetles trapped before flowering \( r^2 = 0.891 \) than during flowering \( r^2 = 0.447 \), whereas in 1999, damage was more closely related to numbers trapped during flowering \( r^2 = 0.930 \). Moreover, the flowering period of raspberry cultivars in Scotland was about twice as long as that of cultivars in Switzerland and Finland. Thus there was more time available for raspberry beetles to oviposit in flowers when the traps were less apparent to the pest because of the growth of primocane foliage. In addition, olfactory stimuli emitted by the flowers may decrease trap efficacy at this stage. Although the extent of fruit damage was not closely related to the numbers of trapped raspberry beetles, there was very little damage at sites with fewer than 5 beetles/trap before flowering. For processed raspberries, a higher threshold of 5-20 raspberry beetles/trap may be acceptable before insecticide control becomes necessary.
Testing chemical enhanced traps

One component of raspberry flowers (coded here as Compound B) was consistently more effective than "Compound A" in trials in 1999. Traps baited with this lure caught significantly more raspberry beetles than did control traps ($P<0.001$). Fig. 2, which summarises the mean numbers of raspberry beetles trapped after 3 or 4 days in successive experiments, shows that traps were most effective during the first two experiments. These were made in May, before cvs Glen Prosen and Glen Rosa had started to flower. Experiments 3 and 4 were done simultaneously in June, when cv. Glen Clova was flowering, and cv. Glen Rosa was just starting to flower. Compound B increased the daily numbers of trapped beetles by a factor of 5-20 times before flowering and 1.5-4 times when traps were exposed after flowering had started. Subsequent tests were made only with "Compound B". Figure 3 compares the mean numbers of raspberry beetles trapped in 4 days in early June, 2001 in plots of cvs Glen Clova and Glen Rosa, using Vertical White or standard sticky traps, with, or without a lure. In this experiment, the volatile was released from a polyethylene sachet because trials in 2000 (Figure 4) showed little difference between the numbers of raspberry beetles caught using a vial or sachet release method. On average, the lure increased the number of trapped raspberry beetles in 2001 by 4 times compared with the numbers on similar traps without lures. Both types of white trap had similar UV reflectance values (data not shown), and this appeared to have an important role in the response of raspberry beetles. Similar numbers were trapped on the Vertical White and standard sticky traps, but very few beetles were caught in the green funnel traps (data not shown).

Figure 2. Numbers of raspberry beetles caught on traps in four trials in 1999.

Figure 3. Numbers of raspberry beetles caught on Vertical White (A) and Standard sticky traps (W) in 2001, with (+), or without (-) lure.

In trials in 2000 with marked raspberry beetles, more "yellow" than "red" beetles were caught, which suggests that the traps are most effective in "attracting" local beetles less than 5m distant from the release sites. Beetles were observed flying upwind towards a volatile-enhanced trap and hovering a few centimetres above it before landing. Although raspberry foliage decreases wind within the plantation, the prevailing wind usually came from the west, and catches on the east face of the white traps were much larger than those on the west face. The local depletion of raspberry beetles suggests that volatile-enhanced white sticky traps could be used to decrease adult populations to such an extent that larval damage falls below economic thresholds, as demonstrated recently with the application of a pheromone+pesticide
In our trial in 2001, two volatile-enhanced traps and two traps without lures, placed in 17.5m row lengths of cv. Glen Rosa, resulted in the removal of about 350 raspberry beetles per replicate. The percentage of damaged fruit, harvested from these rows, was significantly less \((P<0.01)\) than that in control rows, 5-7m from the trap rows. Estimates for damaged fruit in trap and control rows were 23% and 28.5% respectively, with standard errors of 1.48 and 1.59, respectively. Such high amounts of damage are unacceptable for commercial production, but the results are encouraging because the reduction in damage was achieved after the traps had been exposed for only 4 days. Further work is planned to optimise the numbers and spatial arrangement of traps, and periods of trapping in different environmental conditions and pest densities.

Figure 4. Mean numbers of raspberry beetles caught on standard traps baited with "Compound B" in 2001, using a vial or sachet release method.

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References


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Soil pests and their chemical and biological control on strawberry plantations in Poland

Barbara H. Łabanowska, Remigiusz W. Olszak
Research Institute of Pomology and Floriculture, Pomologiczna 18, 96-100 Skierniewice, Poland

Abstract: Strawberry root weevil (Otiorhynchus ovatus), click beetles (Elateridae) and the European cockchafer (Melolontha melolontha) are dangerous soil pests on strawberry plantations in some regions of Poland. The efficacy of some insecticides in controlling strawberry root weevils and white grubs was studied in 1999-2001, both under field and laboratory conditions. Chlorpyrifos (Dursban 480 EC) was used as a standard pesticide. Imidacloprid, bensultap, etofenprox and thiametoxan have given promising results in controlling adult of strawberry root weevils. The first experiments on biological control of strawberry root weevil using Beauveria bassiana were conducted under laboratory and field conditions in 2000 and 2001. This fungus was active, but to have full picture and pronounce an opinion, experiments will be continued in next few years.

Key words: soil pests, strawberry root weevil, Otiorhynchus ovatus, Elateridae, European cockchafer, Melolontha melolontha, Beauveria bassiana

Introduction

Soil pests are a problem on many cultivated plants in Poland and in other countries. On strawberry plantations localised in many regions of Poland, strawberry root weevil (Otiorhynchus ovatus), click beetles (Elateridae) and European cockchafer (white grubs) (Melolontha melolontha) are the most dangerous soil pests. Wireworms and grubs damaged mainly young plants, while strawberry root weevils caused greatest losses on older ones (Penman and Scott, 1976; Łabanowska et al., 1978; Łabanowska, 1994). Wireworms were feeding on neckroots and destroyed them resulting in desiccation of the plant. Larvae damage plants by tunnelling through the roots and crowns, as a result of feeding. In some plantations infested with wireworms between 50-90% of plants had been destroyed. Where white grubs were feeding on roots they caused a sudden collapse of the plants that subsequently dried up. A single wireworm or white grub can damage a few plants. Strawberry root weevil larvae usually damage mostly plants on older plantations. More than one hundred larvae of this pest were found on one strawberry plant. In Poland the most serious roots damage is caused by the later instar larvae in April and May or even in early June. Injured plants become stunted, are weakened and their leaves are smaller. Plants can even be killed when there are too many larvae feeding on them. Circular patches of weak or killed plants can be noticed in the heavily infested field. The most serious damage was observed on plantations in their second year of fruiting and on the older ones. Also much damage was noted on new plantations, which had been replanted in sites of old damaged plantations or near the older, infested fields. There is a need to control strawberry root weevil on many plantations in different regions of Poland. The rotation of fields is also recommended. Although this pest does not fly, new plantations should be planted far from infested fields. If necessary, chlorpyryifos or diazinon can be applied, either as a field preventive treatment before strawberry planting or after the harvest.
On infested cultures in a stage of fruiting the granular formulation of diazinon may also be used in the springtime, before blooming of strawberry.

Many researchers look for some new and more efficient methods of controlling soil pests on different cultures (Bogatko and Labanowski, 1993; Vainio and Hokkanen, 1993; Cross and Burges, 1997; Kakouli-Duarte et al., 1997; Koppenhofer and Kaya, 1998; Malinowski et al., 2001). According to Schmeer et al. (1990), imidacloprid used against the aphids also controls other soil pests on sugar beet.

Material and methods

Experiments on chemical and biological control of soil pests were conducted in 1999-2001 in the Research Institute of Pomology and Floriculture in Skierniewice.

Two different tests with larvae and beetles of the strawberry root weevil were carried out under laboratory conditions. Dursban 480 EC (chlorpyrifos) was used as a standard insecticide. A treatment combination consisted of 25 larvae or beetles per one of three replications. The specimens were collected on an infested strawberry field in June, 1999, then brought to the laboratory and placed in glass jars with soil and treated with 3 different insecticides using a hand sprayer. The efficacy of the insecticides was checked in the third, seventh and fourteenth day after treatment by counting living specimens. The results are expressed as percentage of mortality of larvae and adults (Table 1).

The field tests on controlling strawberry root weevil were performed on several plantations located in the central part of Poland. Complete blocks were the experimental design, each one was 60-2000 sqm in size and containing 4 plots as replications. Emulsified insecticides were used for plant and soil sprayings before bloom and after the harvest. The fungus Beauveria bassiana was applied to the soil after the harvest. The efficacy of the treatments was evaluated in June or early July by counting larvae, pupae and adults of the pest. Six plants per plot, i.e. 24 in each treatment were removed, their roots and sieved soil have been searched for pest's presence. The larvae of European cockchafer were controlled in the field with weeds, before strawberry has been planted. The results were elaborated with analysis of variance on data transformed according to the formula \( y = \log(x+1) \), where \( x \) is the number of specimens. Means differences were evaluated with Duncan's multiple range "t" test at 0.05 significance level. The results are presented in Tables 2-6.

Results

Laboratory test

Imidacloprid (Confidor 200 SL) killed all the larvae (100%) of strawberry root weevil after 7 days, however the beetles after 14 days. Chlorpyrifos in a new formulation (Pyrinex 25 MC) has given a 100% of larvae and beetles mortality after 14 days. The results obtained with both insecticides mentioned above were similar to those with the standard chlorpyrifos formulation (Dursban 480 EC). However after using Dursban 480 EC the pest was killed within 7 days. In untreated containers the mortality of larvae and weevils was similar and reached 16-17% after 14 days (Table 1).

Field experiments

Dursban 480 EC used after the fruit harvest, in July, as a standard insecticide at the rate of 4.0-5.0 l/ha has given a satisfactory result of strawberry root weevil control (Table 2-3). However, the results from the heavily infested plantation in Sierakowice were poorer than those obtained from the less infected plants in Sanniki. Pyrinex 25 MC used at the rate of 10
l/ha has given poorer results when compared to the standard insecticide-Dursban 480 EC and Confidor 200 SL used at the rate 1.0 l/ha. Other chemicals, i.e. bensultap (Bancol 50 WP) and etofenprox (Trebon 10 SC) applied once after the fruit harvest to control the beetles of strawberry root weevil (both at the rate of 2.0 l/ha) showed at least a 50% reduction of its population. The results were a little bit poorer than those obtained with standard insecticide but similar to these with Pyrinex 25 MC. Over 14 individuals per plant were left on untreated plots. Quite good results in chemical control of this pest were noted using the insecticides in the spring, 5-6 weeks before blooming of strawberry. Thiametoxan (Actara 25 WG) applied at the rate of 0.6 kg/ha has shown the same efficacy as chlorpyrifos (Dursban 480 EC) - at the rate of 5.0 l/ha. Both of them gave about 80% reduction of the pest (Table 4).

Table 1. Mortality (%) of the larvae and beetles of the strawberry root weevil- *Otiorhynchus ovatus* L. in laboratory test, 3, 7 and 14 days after treatment (1999)

<table>
<thead>
<tr>
<th>Insecticides and a.i.</th>
<th>Concentration (%)</th>
<th>Days after treatment</th>
<th>Larvae*</th>
<th>Beetles **</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>Confidor 200 SL</td>
<td>0.075%</td>
<td>94.7</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>chlorpyrifos</td>
<td>0.4%</td>
<td>76.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Pyrinex 25 MC</td>
<td>0.8%</td>
<td>50.7</td>
<td>84.0</td>
<td>100.0</td>
</tr>
<tr>
<td>chlorpyrifos</td>
<td>-</td>
<td>2.7</td>
<td>12.0</td>
<td>17.3</td>
</tr>
<tr>
<td>Check (untreated)</td>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

* Date of treatment - 18 of June, 1999
** Date of treatment - 22 of June 1999

Table 2. Efficacy of insecticides in the control of strawberry root weevil- *Otiorhynchus ovatus* L. on strawberry plants

<table>
<thead>
<tr>
<th>Insecticides and a.i.</th>
<th>Rate in l/ha</th>
<th>No. of plants without pest per sample 24 plants*</th>
<th>No. of pest (larvae, pupae, weevils)</th>
<th>Efficacy in %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>average per plant</td>
<td>from - to</td>
<td></td>
</tr>
<tr>
<td>Confidor 200 SL</td>
<td>1.0</td>
<td>3</td>
<td>5.3 c**</td>
<td>0-21</td>
</tr>
<tr>
<td>imidacloprid</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dursban 480 EC</td>
<td>4.0</td>
<td>15.0</td>
<td>1.1 b</td>
<td>0-8</td>
</tr>
<tr>
<td>chlorpyrifos</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dursban 480 EC</td>
<td>5.0</td>
<td>19.0</td>
<td>0.3 a</td>
<td>0-3</td>
</tr>
<tr>
<td>chlorpyrifos</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pyrinex 25 MC</td>
<td>10.0</td>
<td>5</td>
<td>3.2 c</td>
<td>0-11</td>
</tr>
<tr>
<td>chlorpyrifos</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check (untreated)</td>
<td>-</td>
<td>0</td>
<td>14.5 d</td>
<td>5-30</td>
</tr>
</tbody>
</table>

* Date of treatment - 29 of July, 1999 after harvest (The soil was dry)
** Date of counting - 22 of June, 2000, The end of fruit harvest

** Number followed by the same letter do not differ at P=0.05, Duncan’s t-test
Table 3. Efficacy of insecticides in the control of strawberry root weevil - *Otiorhynchus ovatus* L. on strawberry plants

<table>
<thead>
<tr>
<th>Insecticides and a.i.</th>
<th>Rate in l/ha</th>
<th>No. of plants without pest per sample 24 plants*</th>
<th>No. of pest (larvae, pupae, weevils) average per plant from -to</th>
<th>Efficacy in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bancol 50 WP bensultap</td>
<td>2.0</td>
<td>0</td>
<td>11.8 a**</td>
<td>50.2</td>
</tr>
<tr>
<td>Dursban 480 EC chlorpyrifos</td>
<td>5.0</td>
<td>0</td>
<td>8.4 a</td>
<td>64.2</td>
</tr>
<tr>
<td>Pyrinex 25 MC chlorpyrifos</td>
<td>10.0</td>
<td>0</td>
<td>10.4 a</td>
<td>55.6</td>
</tr>
<tr>
<td>Trebon 10 SC etofenprox</td>
<td>2.0</td>
<td>0</td>
<td>10.4 a</td>
<td>55.2</td>
</tr>
<tr>
<td>Check (untreated)</td>
<td>-</td>
<td>0</td>
<td>23.7 b</td>
<td>-</td>
</tr>
</tbody>
</table>

* Date of treatment - 19 of July, 2000
** Date of counting - 12 of July, 2001

** For explanation see Tab. 2

Table 4. Efficacy of some insecticides, used as a soil treatment during early spring, in the control of strawberry root weevil - *Otiorhynchus ovatus* L. on strawberry plants

<table>
<thead>
<tr>
<th>Insecticides and a.i.</th>
<th>Rate in l or kg/ha</th>
<th>Average no. of weevils per plant*</th>
<th>Efficacy in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actara 25 WG thiametoxan</td>
<td>0.6</td>
<td>3.0 a**</td>
<td>79.6</td>
</tr>
<tr>
<td>Dursban 480 EC chlorpyrifos</td>
<td>5.0</td>
<td>3.2 a</td>
<td>80.3</td>
</tr>
<tr>
<td>Check (untreated)</td>
<td>-</td>
<td>16.0 b</td>
<td>-</td>
</tr>
</tbody>
</table>

* Date of treatment - 3 of April, 2001
** Date of counting - 4 of July, 2001

** For explanation see Tab. 2

**Biological control**

The fungus *Beauveria bassiana* propagated on seeds of wheat was applied at the rate of 120 kg/ha in July, after fruit harvest. The results of control were poorer than after applying the standard insecticide (Dursban 480 EC) but still more than 50% of the pest was reduced when compared to untreated plots (Table 5).

**Control of white grubs.**

In an experiment in 2001, thiametoxan (Actara 25 WG at the rate 0.6 kg/ha) and acetamiprid (Mospilan 20 SP at the rate 0.8 kg/ha) were used as a spraying treatment in the field with weeds (before the strawberry has been planted) gave high reduction of the European cockchafer’s larvae (Table 6). The pest population was very high: about 14 larvae/sqm before treatment. After insecticides application and field cultivating the number of pests decreased
down to 1-2.5 larvae/sqm. The number of wireworms was similar on treated and untreated plots.

Table 5. Efficacy of Beauveria bassiana and chlorpyrifos in the control root weevils (Otiorhynchidae) on strawberry plants in the field

<table>
<thead>
<tr>
<th>Combination</th>
<th>Rate in l/kg/ha</th>
<th>Average number of weevils per plant*</th>
<th>Efficacy in %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><em>O.ovatus</em></td>
<td><em>O.sulcatus</em></td>
</tr>
<tr>
<td><strong>Beauveria bassiana</strong></td>
<td>120**</td>
<td>3.4 c***</td>
<td>1.2 b</td>
</tr>
<tr>
<td>Dursban 480 EC chlorpyrifos</td>
<td>5</td>
<td>1.1 ab</td>
<td>0.5 a</td>
</tr>
<tr>
<td>Check (untreated)</td>
<td>-</td>
<td>5.8 c</td>
<td>5.1 c</td>
</tr>
</tbody>
</table>

* Date of treatment - 12 of July, 2000  
Date of counting - 20 of June, 2001  
** on wheat seeds  
*** For explanation see Tab. 2

Table 6. Efficacy of some insecticides, used on the weeds in control of white grubs of European cockchafer - *Melolontha melolontha* L. in the field

<table>
<thead>
<tr>
<th>Insecticides and a.i.</th>
<th>Rate in kg/ha</th>
<th>No of larvae per 1 sqm</th>
<th>Before treatment 29.05.*</th>
<th>After treatment 1.08.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>white grubs</td>
<td>wireworms</td>
<td>white grubs</td>
</tr>
<tr>
<td>Actara 25 WG thiametoxan</td>
<td>0.6</td>
<td>14</td>
<td>2.2 a**</td>
<td>1.0</td>
</tr>
<tr>
<td>Mospilan 20 SP acetamiprid</td>
<td>0.8</td>
<td>14</td>
<td>0.6 a</td>
<td>1.0</td>
</tr>
<tr>
<td>Check (untreated)</td>
<td>-</td>
<td>14</td>
<td>17.8 b</td>
<td>1.5</td>
</tr>
</tbody>
</table>

* Date of treatment - 14 of June, 2001  
Date of counting - 1 of August, 2001  
** For explanation see Tab. 2

Discussion

In laboratory tests imidacloprid (Confidor 200 SL) gave very good results in control of strawberry root weevil. Larvae were killed much quicker than beetles. The above mentioned insecticide showed quite good reduction of strawberry root weevils in the field when used in the summertime, after fruit harvest. These results confirmed earlier Schmeer et al. (1990) data stating that imidacloprid controls soil pests. Imidacloprid gave similar or a little bit poorer results than these obtained with Dursban 480 EC, the best one used in the experiment. Other systemic insecticides like acetamiprid (Mospilan 20 SP) and thiametoxan (Actara 25 WG) have also given good and promising results in control of soil pest feeding on roots. Thiametoxan gave about 80% efficacy in controlling the larvae of strawberry root weevil after
treatment in early spring and reduced over 80% of the white grubs feeding on the weed roots, after treating weeds in June. The control of strawberry root weevil in spring with thiametoxan was similar to that obtained with the standard-chlorpyrifos. Acetamiprid highly reduced the number of white grubs feeding on roots of weeds, when applied on their leaves. In laboratory conditions chlorpyrifos (Pyrinex 25 MC) has shown satisfactory results in controlling larvae and beetles of strawberry root weevil, though its activity was slower than activity of the standard insecticide. In field conditions the results obtained by using Pyrinex 25 MC were quite good though somewhat poorer when compared to the standard insecticide (Dursban 480 EC).

Bensultap (Bancol 50 WP) and etofenprox (Trebon 10 SC), which are used to control weevil pest (e.g. *Anthonomus rubi*, Łabanowska and Masny, 2001) have also shown promising results in reducing strawberry root weevil. These insecticides were applied at the rate twice as big as usually used for controlling pest feeding on leaves. The entomopathogenic fungus *Beauveria bassiana* showed promising results in the first field experiment in control of strawberry root weevil. These results confirmed earlier laboratory tests in that matter (Malinowski et al., 2001).

Conclusions

1. The standard insecticide chlorpyrifos (Dursban 480 EC) gave a good control of soil pests on strawberry plantations.
2. Imidacloprid (Confidor 200 SL), thiametoxan (Actara 25 WG) and chlorpyrifos (Pyrinex 25 MC) gave promising results in control of strawberry root weevil.
3. Acetamiprid (Mospilan 20 SP) and thiametoxan (Actara 25 WG) used together with a mechanical field cultivating gave promising results in control of white grubs.
4. Bensultap (Bancol 50 WP) and etofenprox (Trebon 10 SC) used against weevils of *Otiorhynchus ovatus* feeding on strawberry leaves reduced half of the pest population.
5. Entomopathogenic fungus *Beauveria bassiana* gave promising results in controlling strawberry root weevil.

Acknowledgements

We would like to thank Anna Augustyniuk, Bożena Zaradna, Edyta Będkowska, Stanisław Lesiak and Przemysław Chelkowski for their technical help in conducting the experiment.

References


Influence of some fungicides on the development of two-spotted spider mite (Tetranychus urticae Koch) populations on strawberry

Barbara H. Łabanowska, Beata Meszka
Research Institute of Pomology and Floriculture, Pomologiczna 18, 96-100 Skierniewice, Poland

Abstract: The two-spotted spider mite (Tetranychus urticae) is one of the most important pests of strawberry. Its development rate and fecundity on strawberry depend on the growing season, temperature and cultivar. In the last few years at least one spray treatment was necessary per season to control spider mites on strawberry, mainly in spring. It is known that the fungicide dichlofluanid (as Euparen 50 WP), used to control grey mould (Botrytis cinerea) on strawberry, reduces two-spotted spider mite populations.

In 1995-1996 and 1999-2001, the effect of some fungicides, used for control of grey mould, on development of two-spotted spider mite populations on strawberry was assessed. The best results were obtained with tolyfluanid (Euparen M 50 WG). Procymidone (Sumillex 500 SC), thiophanate-methyl (Topsin 500 SC); BAS 516 GAF also gave good or promising results.

Key words: Two-spotted spider mite, Tetranychus urticae, chemical control, tolyfluanid, dichlofluanid, procymidone, thiophanate-methyl, BAS 516 GAF

Introduction

Two-spotted spider mite (Tetranychus urticae) is one of the most important pests of strawberry. It feeds on many plants, but its development rate and fecundity depend on a growing season, temperature and plant cultivar. Dąbrowski and Rodriguez (1971) and Łabanowska and Chlebowska (1998) reported the different susceptibility of strawberry cultivars to two-spotted spider mite. Numerous mites feeding on leaves decrease yield of strawberry (Kielkiewicz et al., 1986). In many plantations, this pest needs to be controlled in the spring with specific acaricides (Łabanowska, 1995). Some authors also report the influence of dichlofluanid on two-spotted spider mite population development on strawberry (Łabanowska and Bielenin, 1997; Meszka et al., 2000). The aim of this work was to evaluate the influence of some fungicides, used to control grey mould, on development of two-spotted spider mite populations on strawberry.

Materials and methods

The experiments were done in 1995-96 and 1999-2001 at the Research Institute of Pomology and Floriculture, Skierniewice, Poland. They were located on 2-3 year old strawberry plantations. Each experiment was designed in strip blocks where a plot of approximately 50m² (3 rows 14 m long) of strawberry plantation represented one treatment, sub-divided into four plots. A motorised knapsack sprayer "Solo" was used to apply the fungicides at a volume rate of 5 l per plot (1000 l of spraying solution per ha). Two to five treatments were applied during blossom to control grey mould. The influence of the spray on two-spotted spider mite populations was evaluated. The active stages of mites and eggs were counted separately, 3-4 times during the growing season in 4 samples consisting of 30 large leaves taken from each
treatment (total 120 leaves). The mites were counted using the Henderson and McBurnie (1943) technique. The results were analysed statistically on data transformed according to the logarithmic function \( y = \log(x+1) \), where \( x \) was the number of mites per 30 leaves. The significance of differences between means was evaluated using Duncan's multiple range t-test at \( P=0.05 \). Also, Cumulative Indices of Infestation (CII) were calculated according to the formula of Watten et al. (1979) and the CII percentage for each cultivar was established in relation to the CII of the control. The results are presented in tables 1-5.

Results and discussion

Tolyfluanid (Euparen M 50 WG) and dichlofluanid (Euparen 50 WP) used once or twice at the rate of 2 kg/ha gave poorer reductions in spider mite populations than the acaricide hexythiazox (Nissorun 050 EC). The number of mites on plants treated with fungicides were slightly lower than on the untreated till 13th June 1995 in the trial at Kamion (Table 1). In another experiment, Euparen 50 WP applied 4 times during the blossom period against grey mould gave very good reductions in mite populations, to below the economic threshold (Table 2). The results were similar on the two strawberry cultivars, Elsanta and Senga Sengana. In the 1999 experiments, Euparen 50 WP applied 3 or 4 times showed similar results to Euparen 50 WP applied 3 or 4 times plus an additional treatment with Teldor 500 SC (fenhexamid). Other fungicides, procymidone (Sumilex 500 SC) and BAS 516 GAF also reduced the mite population, but the results were poorer in comparison with Euparen 50 WP (Table 3). However, on all treated plants the number of mites was lower than on untreated ones. In the next experiments, Euparen M 50 WG (tolyfluanid) applied 5 times gave a very large reduction in mite populations, to below 1 mite/leaf (Table 4a). Euparen M 50 WG applied twice, reduced mite numbers, but results were poorer than after 5 treatments. Sumilex 500 SC and BAS 516 GAF applied 5 times gave similar results to 2 applications of Euparen M 50 WG, but poorer than 5 applications with Euparen M 50 WG. On all treated plants, numbers of mites were lower in comparison with untreated ones. Good miticidal activity of Euparen M 50 WG was also confirmed in plantations where spider mite was at a high population level (14-15 mites/leaf in June) and 4 fungicide treatments against grey mould, reduced its population to below 1 mite/leaf (Table 4b). After 4 sprays with Topsis 500 SC (thiophanate-methyl) and BAS 516 GAF, the mite population decreased 53 or 68% respectively when compared

<table>
<thead>
<tr>
<th>Table 1. Average number of the two-spotted spider mite (<em>Tetranychus urticae</em> Koch) per leaf of strawberry at Kamion 1995</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fungicide, acaricide and a.i.</strong></td>
</tr>
<tr>
<td>-----------------------------------</td>
</tr>
<tr>
<td>Euparen M 50 WG tolyfluanid</td>
</tr>
<tr>
<td>Euparen 50 WP dichlofluanid</td>
</tr>
<tr>
<td>Nissorun 050 EC hexythiazox</td>
</tr>
<tr>
<td>Control (untreated)</td>
</tr>
</tbody>
</table>

Remark: average classified separately for each date of observations

* Date of treatment: May 20, 1995
** Dates of treatments: May 20 and 30, 1995
Table 2. Average number of the two-spotted spider mite (*Tetranychus urticae* Koch) per leaf of strawberry at Dąbrowice 1996. (Remark: see under Table 1)

<table>
<thead>
<tr>
<th>Fungicide and a.i.</th>
<th>Rate in kg per ha</th>
<th>Number of treatments</th>
<th>Number of mites</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>27.05.</td>
</tr>
<tr>
<td><strong>Senga Sengana</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Euparen 50 WP</td>
<td>5.0</td>
<td>1*</td>
<td>0.5 a</td>
</tr>
<tr>
<td>dichlofluanid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Euparen 50 WP</td>
<td>5.0</td>
<td>4**</td>
<td>0.8 a</td>
</tr>
<tr>
<td>Control (untreated)</td>
<td>-</td>
<td>-</td>
<td>1.4 b</td>
</tr>
<tr>
<td><strong>Elsanta</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Euparen 50 WP</td>
<td>5.0</td>
<td>4**</td>
<td>0.5 a</td>
</tr>
<tr>
<td>dichlofluanid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control (untreated)</td>
<td>-</td>
<td>-</td>
<td>1.3 b</td>
</tr>
</tbody>
</table>

* Date of treatment: May 20; 1996
** Dates of treatment: May 20, 27 and June 3, 7; 1996

Table 3. Average number of the twospotted spider mite (*Tetranychus urticae* Koch) per leaf of strawberry ‘Senga Sengana’ at Skierniewice 1999 (Test 1) and Dąbrowice 1999 (Test 2**) (Remark: see under Table 1)

<table>
<thead>
<tr>
<th>Test 1*</th>
<th>Rate in l or kg per ha</th>
<th>Number of treatments</th>
<th>Number of mites</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>15.06.</td>
</tr>
<tr>
<td>Fungicide and a.i.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Euparen 50 WP</td>
<td>5.0</td>
<td>3</td>
<td>0.1 a</td>
</tr>
<tr>
<td>dichlofluanid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Euparen 50 WP</td>
<td>5.0</td>
<td>3</td>
<td>0.2 a</td>
</tr>
<tr>
<td>dichlofluanid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ Teldor 500 SC</td>
<td>+1.5</td>
<td>+1</td>
<td>4.5 b</td>
</tr>
<tr>
<td>fenhexamid</td>
<td>Control (untreated)</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test 2**</th>
<th>14.06.</th>
<th>29.06.</th>
<th>16.07.</th>
<th>3.08.</th>
<th>CII**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euparen 50 WP</td>
<td>5.0</td>
<td>4</td>
<td>0.1 a</td>
<td>0.2 a</td>
<td>0.3 a</td>
</tr>
<tr>
<td>dichlofluanid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Euparen 50 WP</td>
<td>5.0</td>
<td>4</td>
<td>0.1 a</td>
<td>0.4 a</td>
<td>0.4 a</td>
</tr>
<tr>
<td>dichlofluanid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ Teldor 500 SC</td>
<td>+1.5</td>
<td>+1</td>
<td>0.9 b</td>
<td>0.8 b</td>
<td>0.6 b</td>
</tr>
<tr>
<td>fenhexamid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sumilex 500 SC</td>
<td>1.5</td>
<td>4</td>
<td>1.6 b</td>
<td>1.4 bc</td>
<td>1.5 c</td>
</tr>
<tr>
<td>procydimone</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BAS 516 6AF</td>
<td>1.8</td>
<td>4</td>
<td>1.6 b</td>
<td>1.4 bc</td>
<td>1.5 c</td>
</tr>
<tr>
<td>Control (untreated)</td>
<td>-</td>
<td>-</td>
<td>1.4 b</td>
<td>1.7 c</td>
<td>2.7 d</td>
</tr>
</tbody>
</table>

Dates of treatment:
* May 20 and 25; June 01; 1999  Teldor - June 12
** May 18, 25 and 31; June 4; 1999  Teldor - June 12
CII** - Cumulative Indice of Infestation
with untreated plots. Topsin M 70 WP gave a poorer reduction in mite numbers on heavy infested plants. The last experiment (2001) with Euparen M 50 WG confirmed the earlier results (Table 5). BAS 516 GAF and Sumilex 500 SC applied 4 times gave a satisfactory reduction of the mite population. The poorest results were obtained with Topsin M 70 WP.

Generally, results of several years experiments confirmed that Euparen 50 WP (dichlofluanid) at the rate of 5 kg/ha and Euparen M 50 WG (tolyfluanid) at the rate of 5 kg/ha applied 3-5 times during blossom to control the most important fungus disease - grey mould - in strawberry plantations, also showed satisfactory reduction of the two-spotted spider mite population. These results are in agreement with Łabanowska and Bielenin (1997) and Meszka et al. (2000) who showed that Euparen gave good control of Botrytis cinerea and Tetranychus urticae. Sumilex 500 SC (procymidone) at the rate of 1.5 l/ha and BAS 516 GAF at the rate of 1.8 kg/ha, applied 4-5 times against grey mould, showed at least a 40-50% mite population reduction, depending on the year. These results were poorer than after treatment with Euparen. Topsin 500 SC (thiophanate-methyl) also gave poor results in comparison with Euparen, but was better than Topsin M 70 WP.

---

**Table 4. Average number of the twospotted spider mite (*Tetranychus urticae* Koch) per leaf of strawberry (Senga Sengana) at a) Dąbrowice 2000, b) Miedniewice 2000.**

(Remark: see under Table 1)

<table>
<thead>
<tr>
<th>a) Fungicide and a.i.</th>
<th>Rate in l or kg per ha</th>
<th>Number of treatments</th>
<th>Number of mites per 1 leaf</th>
<th>CII&lt;sup&gt;1/&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>10.06.</td>
<td>19.06.</td>
<td>10.07.</td>
</tr>
<tr>
<td>Euparen M 50 WG</td>
<td>5.0</td>
<td>2*</td>
<td>1.5 b</td>
<td>4.2 b</td>
</tr>
<tr>
<td>tolyfluanid</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Euparen M 50 WG</td>
<td>5.0</td>
<td>5**</td>
<td>0.4 a</td>
<td>0.3 a</td>
</tr>
<tr>
<td>Sumilex 500 SC</td>
<td>1.5</td>
<td>2*</td>
<td>5.1 d</td>
<td>7.3 b</td>
</tr>
<tr>
<td>procymidone</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sumilex 500 SC</td>
<td>1.5</td>
<td>5**</td>
<td>3.9 cd</td>
<td>6.2 b</td>
</tr>
<tr>
<td>BAS 516 GAF</td>
<td>1.8</td>
<td>5**</td>
<td>2.8 c</td>
<td>4.9 b</td>
</tr>
<tr>
<td>Control (untreated)</td>
<td>-</td>
<td>-</td>
<td>9.2 e</td>
<td>7.3 b</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>b)</th>
<th>2.06.</th>
<th>19.06.</th>
<th>CII&lt;sup&gt;1/&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euparen M 50 WG</td>
<td>5.0</td>
<td>4***</td>
<td>0.6 a</td>
</tr>
<tr>
<td>tolyfluanid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BAS 516 GAF</td>
<td>1.8</td>
<td>4</td>
<td>9.7</td>
</tr>
<tr>
<td>Topsin M 70 WP</td>
<td>2.5</td>
<td>4</td>
<td>13.4 c</td>
</tr>
<tr>
<td>thiophanate methyl</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topsin 500 SC</td>
<td>2.25</td>
<td>4</td>
<td>7.7 b</td>
</tr>
<tr>
<td>Control (untreated)</td>
<td>-</td>
<td>-</td>
<td>14.2 c</td>
</tr>
</tbody>
</table>

Dates of treatments:

* May 19 and 31, 2000
** May 5, 10, 16, 22 and 31, 2000
*** May 4, 10, 16 and 23, 2000

<sup>1/</sup> CII - cumulative Indice of Infestation
Table 5. Average number of the twospotted spider mite (*Tetranychus urticae* Koch) per leaf of strawberry 2001

<table>
<thead>
<tr>
<th>Fungicide and a.i.</th>
<th>Rate in l or kg per ha</th>
<th>Number of treatments</th>
<th>Number of mites per 1 leaf</th>
<th>Experiment I</th>
<th>Exp. II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>13.06.</td>
<td>9.07.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>31.07.</td>
<td>17.08.</td>
</tr>
<tr>
<td>Sumilex 500 SC procymidone</td>
<td>1.5</td>
<td>4</td>
<td>1.0</td>
<td>1.1</td>
<td>0.6</td>
</tr>
<tr>
<td>Tospin M 70 WP thiophanate methyl</td>
<td>2.5</td>
<td>4</td>
<td>2.0</td>
<td>2.6</td>
<td>1.0</td>
</tr>
<tr>
<td>Euparen M 50 WG tolyfluanid</td>
<td>5.0</td>
<td>4</td>
<td>0.5</td>
<td>1.7</td>
<td>0.7</td>
</tr>
<tr>
<td>BAS 516 GAF</td>
<td>1.8</td>
<td>4</td>
<td>-</td>
<td>0.4</td>
<td>0.3</td>
</tr>
<tr>
<td>Control (untreated)</td>
<td>-</td>
<td>-</td>
<td>2.8</td>
<td>3.9</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Dates of treatments:
Experiment I  – Dąbrowice: May 16, 23, 31 and June 6, 2001
Experiment II – Miedniewice: May 17, 22, 30 and June 6, 2001

Conclusions

1. Euparen 50 WP (dichlofluanid) and Euparen M 50 WG (tolyfluanid), applied 3-5 times at the rate of 5 kg/ha to control *Botrytis cinerea*, gave good reductions in two-spotted spider mite populations. One or two treatments with Euparen (5 kg/ha) gave poorer results as did lower rates of the fungicide (2 kg/ha).
2. Sumilex 500 SC (procymidone) at the rate of 1.5 kg/ha, Tospin 500 SC (thiophanate-methyl) at the rate of 2.25 l/ha and BAS 516 GAF at the rate of 1.8 kg/ha, reduced *T. urticae* populations by about 50% after 4-5 applications against *B. cinerea*.

Acknowledgement

We would like to thank Anna Bielenin for consultations and Bożena Zaradna for technical help in conducting the experiment.

References

Phytoseiids for control of spider mite, *Tetranychus urticae*, and tarsonemid mite, *Phytonemus pallidus*, on strawberry in UK

Jean Fitzgerald, Mike Easterbrook  
Horticulture Research International, East Malling, Kent, ME19 6BJ, UK

**Abstract:** Four species of predatory phytoseiid mite, *Neoseiulus cucumeris*, *N. californicus*, *N. aurescens* and *Typhlodromus pyri*, developed from the egg stage to adult when fed on immature tarsonemid mites. None of these predators appeared to be able to consume tarsonemid eggs. *Phytoseiulus persimilis* was unable to develop when provided with tarsonemid mites as prey. In a field experiment designed to determine optimal release rates for *N. cucumeris*, *N. aurescens* colonised the plants and it was not possible to demonstrate the effectiveness of either species as a biocontrol agent for tarsonemids. Field experiments showed that *Neoseiulus californicus* is capable of providing biological control of two-spotted spider mite on field grown protected strawberry.

**Key words:** phytoseiids, biocontrol, *Phytonemus pallidus, Tetranychus urticae*, strawberry

**Introduction**

Feeding by spider mites, *Tetranychus urticae*, on strawberry results in damage to the leaves and reduced plant vigour, leading to loss of yield. Tarsonemid mites (*Phytonemus pallidus*) feed on the developing leaves, causing them to become misshapen, and the plant to become stunted. Both species of mites can become serious problems on crops grown under plastic or glass, because of the higher temperatures under protection. Everbearer strawberries crop until October; because of the long fruiting period there are constraints on the use of pesticides on the plants. There are currently no acaricides registered for control of tarsonemid mites in UK. For these reasons there is increasing interest in use of biocontrol agents against mite pests.

In UK two species of phytoseiid mites (*Phytoseiulus persimilis* and *Neoseiulus cucumeris*) are available commercially for release into plantations, and three species (*Typhlodromus pyri, Neoseiulus aurescens* and *Neoseiulus californicus*) have been found naturally colonising strawberry plantations. *Neoseiulus californicus* is not native to the UK; releases were made in the mid 1990s when the species was mistakenly synonymised with a native species. Since then it has been found in many soft fruit plantations in SE England (Jolly 2001), and appears to be successfully overwintering. However there is currently no licence to release this species in open field situations. *Phytoseiulus persimilis* has been shown to effectively control spider mite numbers in field grown strawberries, whereas *T. pyri*, which is an important predator of spider mite and eriophyid mites on apple (Solomon et al., 1993), was less effective (Easterbrook, 1992). In glasshouse experiments, Easterbrook et al. (2001) showed that both *N. cucumeris* and *N. californicus* significantly reduced numbers of tarsonemids on potted strawberry plants; control of tarsonemids by *N. cucumeris* was significantly better at predator prey ratios of 1:10 and 1:20 than at 1:40. Spider mites were also controlled effectively at a release rate of 20 *N. cucumeris*/plant.

The laboratory experiments described in this paper were undertaken to determine if the phytoseiid species found naturally in strawberry plantations in UK, and those species available for artificial release, could develop when fed only on tarsonemids. The field
experiments were undertaken to determine the effectiveness of *Neoseiulus cucumeris* and *N. californicus* as control agents for spider mites and tarsonemid mites in field situations.

**Methods**

*Feeding studies*
In laboratory experiments the ability of five species of phytoseiid mites to develop from egg to adult when fed on tarsonemid prey, and their rates of development, were determined. All experiments were done on leaf disc arenas at a constant temperature of 20°C. Mites were inspected each day and prey replenished as necessary, so that there was always a surplus.

*Field experiments*
The replicated field experiments were done under polytunnels and used large plantings of strawberry plants (approx 0.1ha), with 2m gaps between treatments to restrict predator redistribution. Experiments were designed to determine suitable release rates of *N. cucumeris* for control of tarsonemid mites and *T. urticae*, and the effectiveness of *N. californicus* to control *T. urticae*. In the first experiment each sample consisted of five very young leaves and five flower cluster samples from each plot, each sample unit being taken from a different plant. In the second experiment, 30 leaflets (one third of tri-foliate leaf) were taken per plot. Samples were taken before predator release and at intervals after release. Mite numbers were counted under a stereomicroscope in the laboratory.

**Results**

*Feeding experiments*
In laboratory experiments the predatory phytoseiid mite *Phytoseiulus persimilis* was unable to develop when fed on any stage of tarsonemid mites. *Neoseiulus cucumeris* and *N. californicus* were able to develop to the adult stage when fed on tarsonemid nymphs or adults. Adults of both species consumed up to 40 tarsonemid nymphs over a seven-hour period. *Neoseiulus aurescens* was able to feed on tarsonemid nymphs and complete development on this diet. *Typhlodromus pyri* also developed to adult when fed on tarsonemid nymphs, but not when fed adults.

Development of *T. pyri* took 7-9 days at 20°C, feeding on immature tarsonemids, which was slower than any of the *Neoseiulus* species tested (Table 1). None of these predators consumed tarsonemid eggs.

<table>
<thead>
<tr>
<th>Phytoseiid species</th>
<th>Time in days ± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Neoseiulus cucumeris</em></td>
<td>5.6 ±0.22</td>
</tr>
<tr>
<td><em>Neoseiulus californicus</em></td>
<td>5.0 ±0.43</td>
</tr>
<tr>
<td><em>Neoseiulus aurescens</em></td>
<td>5.5 ±0.67</td>
</tr>
<tr>
<td><em>Typhlodromus pyri</em></td>
<td>8.3 ±0.48</td>
</tr>
<tr>
<td><em>Phytoseiulus persimilis</em></td>
<td>Did not develop</td>
</tr>
</tbody>
</table>
Field experiments

In a field experiment where initial releases of 2 or 10 *N. cucumeris* per plant were made on strawberries grown under polytunnels, numbers of tarsonemids were lowest at the highest rate of release of *N. cucumeris* 7 days after release (DAR), but these results were not statistically significant (Table 2). Samples taken from the experimental plants showed that plants in all treatments had been colonised by another species of phytoseiid mite, *Neoseiulus aurescens* (Table 2). Initial laboratory tests with this phytoseiid have indicated that it consumes tarsonemids (see above in Table 1), so it merits further study, particularly as it survived an insecticide application designed to eliminate phytoseiids from the plants at the beginning of the experiment. However, in this field experiment there was no evidence that *N. aurescens* had reduced tarsonemid numbers, as populations increased between 7 DAR and 27 DAR (Table 2) in spite of the large numbers of phytoseiids on the plants.

Table 2. Mean numbers of tarsonemid mites and *N. cucumeris* and *N. aurescens* in field grown strawberry under protection, where initially different release rates of *N. cucumeris* were made

<table>
<thead>
<tr>
<th><em>N. cucumeris</em> release rate</th>
<th>Mean numbers of mites ±SE per 10 sample units</th>
<th>7 DAR</th>
<th>27 DAR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>N. aurescens</em></td>
<td><em>N. cucumeris</em></td>
<td><em>N. aurescens</em></td>
</tr>
<tr>
<td>0</td>
<td>36.6±8.7</td>
<td>16.0±6.1</td>
<td>0.2±0.2</td>
</tr>
<tr>
<td>2</td>
<td>34.6±6.3</td>
<td>14.0±7.5</td>
<td>1.4±0.4</td>
</tr>
<tr>
<td>10</td>
<td>24.4±5.3</td>
<td>8.2±1.8</td>
<td>3.0±0.3</td>
</tr>
</tbody>
</table>

Table 3. Control of *Tetranychus urticae* with *Neoseiulus californicus* in field grown strawberry under protection

<table>
<thead>
<tr>
<th><em>N. californicus</em></th>
<th>Mean numbers of <em>T. urticae</em> per leaflet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11 DAT</td>
</tr>
<tr>
<td></td>
<td>active stages</td>
</tr>
<tr>
<td></td>
<td>mean</td>
</tr>
<tr>
<td><em>N. californicus</em> present</td>
<td>26.8</td>
</tr>
<tr>
<td><em>N. californicus</em> removed</td>
<td>94.2</td>
</tr>
<tr>
<td>SED (4 df)</td>
<td>0.43</td>
</tr>
<tr>
<td>P-value</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

*3df
In another field experiment under polytunnels, two release rates of *N. cucumeris* (2 and 12 per plant) were compared for control of spider mite. By 11 DAR there were similar numbers of phytoseiid mites in all treatments, with a range of 0.1-1.0 adults and 0.2-3.8 eggs per leaflet. These mites were identified as *N. californicus*, which appeared to have colonised the strawberries from another experimental plot, and had overwintered successfully. The presence of *N. californicus* obscured any effects of the *N. cucumeris* release. The populations of *N. californicus* were significantly reduced on some parts of the field with an insecticide; mean number of active mites was 7 in the untreated plots and 1.5 in insecticide treated plots (P<0.01) 11 DAT. It was then possible to demonstrate that this species gave significant reductions in numbers of spider mites. By 11 DAT numbers of *T. urticae* eggs and active stages were significantly lower in plots where *N. californicus* numbers had not been reduced (Table 3). The difference in *T. urticae* numbers in the two treatments was also significant 21 DAT. Samples of phytoseiids were taken from all treatment plots during this experiment and no *N. cucumeris* were found, indicating that *N. californicus* had out-competed *N. cucumeris*, which had failed to establish.

**Discussion**

These and previous experiments have shown that the predatory mites *Neoseiulus cucumeris* and *N. californicus* have great potential as biocontrol agents for tarsonemid mite on strawberry, but there are constraints on the ways these species can be exploited. *Neoseiulus cucumeris* can be released in the field, but at present it is not permitted to release the non-native species *N. californicus*. However, it is apparent from our research that *N. californicus* is established in S England and readily colonises strawberry plantations. Neither *N. cucumeris* nor *N. californicus* will totally eliminate tarsonemid mites, probably because the tarsonemids occupy extremely cryptic microhabitats, which the larger life stages of the phytoseiids find difficult to access. Also, neither *Neoseiulus* species consumed tarsonemid eggs when presented with them in laboratory feeding tests, although they developed successfully to adult on other tarsonemid life stages. Provided that predator release is done before tarsonemid numbers get too high they should prevent tarsonemids causing economic damage to the plants (Easterbrook et al., 2001). In experiments in the USA on potted strawberry plants, *N. cucumeris* gave reasonable control of moderate densities of tarsonemids (Croft et al., 1998). Glasshouse experiments suggested that when *P. pallidus* and *T. urticae* are both present, *N. cucumeris* will give reasonable control of the tarsonemid, and limited control of the spider mite (Easterbrook et al., 2001).

In our experiments *Neoseiulus californicus* was shown to be capable of providing biological control of two-spotted spider mite in field grown strawberries. This species has also been reported to give successful control of spider mite in Spain (Garcia-Mari and Gonzalez-Zamora, 1999). It also has the advantage of being resistant to many pesticides (Easterbrook unpublished). This contrasts with the situation with *Phytoseiulus persimilis*, the predatory mite used by growers against spider mite at present, which is susceptible to many insecticides and does not provide any control of tarsonemids. It is possible that a mixture of *N. cucumeris* and *N. californicus* may provide control of both spider mites and tarsonemids, but further research is required to study the interactions between the two phytoseiid species.

*Neoseiulus aurescens* has been recorded as a predator of tarsonemid mites on strawberry in California (Strand, 1994), and with the preliminary results obtained here this suggests that this species merits further study. It has also been reported to feed on thrips in glasshouse crops in Latvia (Petrova et al., 1997).
Typhlodromus pyri was also shown to be able to develop from egg to adult when fed on immature tarsonemid mites. In earlier studies it was shown to contribute to biocontrol of spider mites in field grown strawberries (Easterbrook, 1992).

It is evident that the mite predator/prey relationships on strawberry, involving the pests (tarsonemid and spider mites) and the several species of predators that either colonise strawberry naturally (T. pyri, N. californicus and now N. aurescens) or can be introduced artificially (N. cucumeris and P. persimilis), constitute a complicated matrix of relationships. If the potential of these two types of predator is to be exploited optimally, then it is necessary to understand the interactions existing among these species, including possible antagonistic relationships between predator species. We are developing PCR techniques for detecting prey DNA in the predator gut; these molecular methods will be used, together with laboratory and field experiments, to elucidate the mite predator/prey relationships on strawberry. This will provide a basis for the development of biocontrol strategies that optimise the deployment of artificially released predators according to the biocontrol potential of the predatory species that may already have colonised the plantation.

Acknowledgements

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References


Biological control of *Tetranychus urticae* on plastic covered raspberries with native and introduced phytoseiids

Christian Linder¹, Charly Mittaz², Christoph Carlen²

¹ Federal Research Station on Plant Production of Changins, Route de Duillier, PostBox 254, CH-1260 Nyon, Switzerland
² Federal Research Station on Plant Production of Changins, Arboricultural and Horticultural Centre des Fougères, CH-1964 Conthey, Switzerland

**Abstract:** A biological control experiment was conducted in 2000, in eastern Switzerland, against the two-spotted spider mite, *Tetranychus urticae*, on autumn fruiting raspberries cv Autumn Bliss grown in plastic tunnels. The indigenous predatory mite, *Amblyseius andersoni*, was compared to *Phytoseiulis persimilis* introduced once or twice at a density of 10 mites per m². A misting system was installed to favor the predatory mites and suppress *T. urticae*. The best control was achieved with misting and two releases of *P. persimilis* thereby reducing the pest pressure to 480 *T. urticae*-days / terminal leaflet. Without misting and with *A. andersoni* alone, pest pressure reached 2200. Nevertheless, misting did not offer all the expected advantages. *A. andersoni* was able to overwinter at the base (0 to 40 cm) of the shoots whereas *P. persimilis* disappeared from the crop. Conserving the base of the shoots in the spring permits a rapid colonization by *A. andersoni*. Therefore, in the spring of 2001, the tunnels without the introduction of *P. persimilis* were very rapidly colonized by *A. andersoni*. In the other tunnels, colonization by *A. andersoni* was slow indicating an important interspecific competition the previous season.

**Key words:** Biological control, raspberries, *Tetranychus urticae*, *Phytoseiulis persimilis*, *Amblyseius andersoni*

**Introduction**

The biological control of the two-spotted spider mite, *Tetranychus urticae* Koch (TU), by the use of various indigenous or introduced predatory mites is currently under development in several countries (Charles et al., 1985; Wood et al., 1994; Höhn et al., 1995; Baillod et al., 1996; Meesters et al., 1998; Tuovinen et al., 2000). The mite *Phytoseiulis persimilis* Athias-Henriot (PP) figures among the most commonly tested non-native predators. The contrasting results obtained using this phytoseiid have often been put down to unfavourable climatic conditions (cool nights, low relative humidity...). Therefore in order to create more favourable conditions for the development of this predator, an experiment to test misting was set up on a farm in eastern Switzerland. At the same time the development of the native predatory mite *Amblyseius andersoni* Chant (AA) was followed up and the interspecific relationships observed are discussed below.

**Material and methods**

**Farming data**

The trial was conducted on a farm situated by Lake Constance (450 m) in eastern Switzerland (Thurgau). The experiments were carried out in 6 plastic tunnels measuring 45 x 6 m using the autumn fruiting cv Autumn Bliss planted in 3 rows of 0.4 m. The different variants are given in Table 1.
Table 1. Variants tested in the Biological Control Trial 2000.

<table>
<thead>
<tr>
<th>Tunnels</th>
<th>Predatory mites</th>
<th>Releases</th>
<th>Misting</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td><em>A. andersoni</em></td>
<td>native</td>
<td>yes</td>
</tr>
<tr>
<td>2.</td>
<td><em>A. andersoni</em> + <em>P. persimilis</em></td>
<td>PP : twice, 10 /m², 6.07 and 4.08</td>
<td>yes</td>
</tr>
<tr>
<td>3.</td>
<td><em>A. andersoni</em> + <em>P. persimilis</em></td>
<td>PP : once, 10 /m², 4.08</td>
<td>yes</td>
</tr>
<tr>
<td>4.</td>
<td><em>A. andersoni</em> + <em>P. persimilis</em></td>
<td>PP : twice, 10 /m², 6.07 and 4.08</td>
<td>no</td>
</tr>
<tr>
<td>5.</td>
<td><em>A. andersoni</em> + <em>P. persimilis</em></td>
<td>PP : once, 10 /m², 4.08</td>
<td>no</td>
</tr>
<tr>
<td>6.</td>
<td><em>A. andersoni</em></td>
<td>native</td>
<td>no</td>
</tr>
</tbody>
</table>

The misting system functioned for 3 minutes at intervals of 15 minutes as soon as temperatures rose above 27°C. It was stopped during the month of August to avoid heavy calcareous deposits on foliage. Climatic data (temperature, relative humidity) were recorded every 10 minutes by two OPUS probes. Chemical treatments applied during the trial are shown in Table 2.

Table 2. Treatments applied during the Biological Control Trial 2000.

<table>
<thead>
<tr>
<th>Dates</th>
<th>Trade Mark (% active ingredient)</th>
<th>Concentrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>31.03.2000</td>
<td>Phosalone (33.7% phosalone)</td>
<td>0.15%</td>
</tr>
<tr>
<td>12.07.2000</td>
<td>Pirimor (50% pirimicarbe)</td>
<td>0.05%</td>
</tr>
</tbody>
</table>

Checkings

An estimation of TU and phytoseiid populations was made by checking 25 terminal leaflets per variant every 15 days, approximately, from May to the end of November. The number of TU mobile forms and eggs was estimated under binocular magnifying glasses using a class system (Guignard, 1968). Phytoseiid mobiles forms and eggs were counted exactly. The main results are expressed in terms of number of mobile forms per terminal leaflet and mite-days per terminal leaflet.

Hibernating mite populations were checked by removing 25 wooden canes per tunnel at the end of the growing season. These canes were separated into two distinct groups according to height: 0 to 40 cm and 40 to 80 cm. They were then placed in a modified system of Berlese funnels for one week; the mites collected were counted under binocular magnifying glasses.

Results and discussion

Misting

The effects of misting on the climate in the tunnels are summarised in Table 3. The system had little influence on temperature and relative humidity. No particular mycological problems were observed during the trial.

Table 3. Mean climatic data from 10.05.2000 to 13.12.2000 (from the centre of tunnels)

<table>
<thead>
<tr>
<th>Variants</th>
<th>Temperature °C</th>
<th>RH %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without misting</td>
<td>14.7</td>
<td>81.37</td>
</tr>
<tr>
<td>With misting</td>
<td>14.5</td>
<td>83.06</td>
</tr>
</tbody>
</table>
Population dynamics

Figures 1 and 2 show the observed dynamics in the two variants where populations of TU were the greatest and the lowest, respectively. Table 4 gives results expressed in mite-days per terminal leaflet and allows a direct comparison between all tested variants.

Figure 1. Population dynamics of mites in the variant *A. andersoni* – without misting (tunnel no. 6) and proportion of observed phytoseiid species.

Examination of Fig. 1 reveals an important development of TU during August reaching a peak of 68.4 mobile forms per terminal leaflet at the beginning of September. In parallel, the number of AA mobile forms per leaf rises to 17 by mid-September. This major development helps to explain the collapse of the TU populations in the autumn. AA, however, continues to hold out very satisfactorily in the cultivations, in spite of the absence of prey. A negligible number of PP coming from neighbouring tunnels can be seen in the graph of species proportions.

Figure 2. Populations dynamics of mites in the variant *A. andersoni* and *P. persimilis* – with misting (tunnel no. 2) and proportion of observed phytoseiid species. Releases are represented by the two arrows.
Fig. 2 shows a much more modest peak of observed TU (12.9 mobiles forms per terminal leaflet) and a more rapidly declining population than in the first case. Equally, it is clear that PP develops with difficulty after the first release, in spite of misting and the presence of prey. Indeed, it is only after the second introduction at the beginning of August that a significant increase in populations is seen overtaking those of AA, at which time the misting system was no longer working! In the autumn, in the absence of prey, PP falls off rapidly; the same phenomenon is true of AA which remains only sporadically throughout the cultivations. The drop in numbers of this latter species is linked to competition from PP which probably also feeds on AA due to lack of TU.

Table 4. Total load of mites expressed in mite-days / terminal leaflet.

<table>
<thead>
<tr>
<th>Tunnels (+ : misting)</th>
<th>TU-days</th>
<th>AA-days</th>
<th>PP-days (releases)</th>
<th>Predators-days</th>
<th>Proportion of predators species</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AA</td>
<td>PP</td>
<td>AA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. +</td>
<td>1879</td>
<td>411</td>
<td>41</td>
<td>452</td>
<td>90.9</td>
</tr>
<tr>
<td>2. +</td>
<td>483</td>
<td>167</td>
<td>97 (2)</td>
<td>264</td>
<td>63.2</td>
</tr>
<tr>
<td>3. +</td>
<td>1543</td>
<td>212</td>
<td>165 (1)</td>
<td>377</td>
<td>56.2</td>
</tr>
<tr>
<td>4. +</td>
<td>719</td>
<td>213</td>
<td>274 (2)</td>
<td>487</td>
<td>43.7</td>
</tr>
<tr>
<td>5. +</td>
<td>1556</td>
<td>401</td>
<td>126 (1)</td>
<td>527</td>
<td>76.1</td>
</tr>
<tr>
<td>6. +</td>
<td>2252</td>
<td>561</td>
<td>5</td>
<td>566</td>
<td>99.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1879</td>
<td>411</td>
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<td>417</td>
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<tr>
<td></td>
<td>2252</td>
<td>561</td>
<td>5</td>
<td>566</td>
<td>99.1</td>
</tr>
</tbody>
</table>

Under trial conditions two releases of PP sufficed to maintain TU at a relatively low level (tunnels 2 and 4). AA alone did not achieve the same results (tunnels 1 and 6). A single PP introduction resulted in some control but the final load in TU-days was, however, superior to that obtained with two releases. These results can be explained by PP’s voracious appetite, its dispersion capacities together with an intrinsic level of natural growth (number of female descendants per female per day) higher than AA.

It is difficult to estimate the influence of misting especially since the system was not functioning during the month of August. The greatest development of PP was obtained in tunnel 4 without misting whereas in tunnel 2, with misting, it was the lowest. It would appear that the development of predators is more closely linked to abundant prey than to misting.

A better understanding of the relation between TU-days and harvesting parameters (yield, quality of fruit) would permit an objective evaluation of the superiority of one variant compared with another. Even though no precise measurements were made during this trial, it should be mentioned that no significant differences between the six tunnels were noticed by the producer. Studies carried out in Canada by Raworth (1989) have shown that no losses in yield have come to light with accumulated TU populations of up to 7300 mite-days / leaflet even though distinct leaf discoloration was observed. Although these results obtained from different varieties can in no way be extrapolated to our data, if theses values were confirmed it becomes evident that the relatively costly release of PP would not be beneficial and that AA would be sufficient to keep TU populations at an acceptable level.

**Hibernation of mites**

Checks have revealed that only AA can be found in large quantities in the cultivations during conditions of Swiss winters and that PP totally disappears. The 0 to 40 cm group sheltered the
most individuals since a larger number of growth niches provided greater possibility for hibernating (Figure 3). Furthermore, in tunnels 2 and 4 where two PP releases were made in 2000, a very low number of AA was observed. This clearly illustrates the interspecific competition between the two predators.

As a result of these observations, the producer left cane bases in the fields after February pruning and only removed the wood in April at which time a renewed check showed that AA had left its winter quarters to colonise young shoots. The first check in the spring of 2001 confirmed these observations and showed an excellent percentage of leaves occupied by AA in all tunnels except tunnels 2 and 4 (Figure 3).

![Figure 3. Hibernation patterns of *A. andersoni* in raspberry canes according to height of wooden canes and percentage of terminal leaflets occupied by *A. andersoni* at the first check 2001.](image)

By leaving the bases of the previous year’s canes in the cultivation, a very rapid colonisation by AA was possible in the spring 2001. Compared with the season in 2000, the first AA populations were not observed at similar levels until the end of June. In tunnels 2 and 4, AA populations increased slowly to reach the same levels as other tunnels from July 2001. Fortunately, no TU attack occurred in these variants which would have obliged us to carry out an early PP introduction.

Thus the use of AA in the biological control of cultivations under plastic cover with or without misting systems appears promising. The first results of 2001 tend to confirm this impression. This system of control can be further improved by leaving wooden canes in place for some time after spring pruning so that predators can rapidly transfer to young shoots. In this way the plants are immediately colonised by AA which is then well prepared for TU attacks. Moreover, the risk of fungal diseases transmission is very low in this kind of cultivation system. The use of PP in conjunction with AA is a double-edged weapon: it allows very good control of TU but may cause the disappearance of AA from cultivations for the following year thus necessitating costly releases. Release of PP should therefore only be envisaged in situations where native predatory mites cannot cope with TU attacks alone or in cultivations where they are totally absent.

In addition, this trial has illustrated the need for precise measurements of TU harmfulness in raspberry cultures so that the interpretation of results is facilitated and the least expensive control strategies can be selected.
Acknowledgments

We wish to thank Mr. W. Müller, producer, for making his raspberry plots available to us and the firm Omya AG, Switzerland, for the free supply of predatory mites.

References


Guignard, E. 1968: Méthode de contrôle visuel du nombre des acariens par feuille utilisée dans la lutte intégrée (méthode des classes). Station fédérale de recherches en production végétale, Changins, rapport interne non publié.


Genetic variation in raspberry beetles and possible role of their bacterial endosymbionts in pest management

G. Malloch, B. Fenton
Scottish Crop Research Institute, Invergowrie, Dundee DD2 5DA, Scotland, UK

Abstract: *Byturus tomentosus* (raspberry beetle) and *B. unicolor* (raspberry fruitworm) are important byturid beetle pests of raspberry in Europe and North America respectively. These pests are controlled by the application of insecticides. Developing alternative control measures requires knowledge of the relationships within and between these pests and similar organisms found in natural and agricultural situations. DNA analysis is the most direct method of studying genetic material that is possible and, in contrast to morphometrics, it is independent of life stage and any environmentally mediated variation. Here we studied Byturidae (Coleoptera) inter-specific relationships using nuclear ribosomal ITS2 and mitochondrial cytochrome oxidase DNA sequences. Phylogenetic trees based on the mitochondrial and ribosomal sequences were generated. There was evidence that the raspberry fruitworm, *B. unicolor*, is divided into at least three distinct groupings. The American species was not the most related to the European raspberry beetle. Instead, links between *B. affinis* from Japan and the American beetle suggest that this lineage originated in Asia and colonised the western USA. More than 99% of UK *B. tomentosus* individuals are infected with the bacterial endosymbiont *Wolbachia*. In other arthropods this group of bacteria is known to alter host reproduction by inducing parthenogenesis, feminisation of genetic males, son killing and cytoplasmic incompatibility.

Key words: raspberry beetle, *Byturus tomentosus*, phylogeny, *Wolbachia*

Introduction

The taxonomy of the Byturidae has been revised on a number of occasions and at present there are 16 recognised species in seven genera (Springer and Goodrich 1983, 1986, 1990, 1994; Goodrich and Springer 1987, 1988, 1995). This group of beetles is of interest as it contains agricultural pests as well as endangered species. The two pests are *Byturus tomentosus* (DeGeer), the European raspberry beetle, which damages the European raspberry *Rubus idaeus* var *idaeus*, and *B. unicolor* (Say), the American raspberry fruitworm, which affects fruit production of the American raspberry *R. idaeus* var *strigosus*. Originally Barber (1942) described *B. unicolor* as four species *B. sordidus*, *B. bakeri*, *B. rubi* and *B. unicolor*. In 1983 Springer and Goodrich re-examined specimens and placed them all in synonymy with *B. unicolor*.

Despite being geographically separated, the American and European raspberry beetle species share similar life histories and habitats. However, the parameters that may have influenced their divergence are not fully understood. Reproductive incompatibility is a common phenomenon in some arthropods and is caused by a rickettsia-like micro-organism, *Wolbachia*, which is maternally inherited and transmitted through the egg cytoplasm (O’Neill et al., 1992). *Wolbachia* can cause partial to complete embryonic death in crosses between insect hosts that are infected and uninfected, as well as those infected with different bacterial types. Cytoplasmic incompatibility decreases the fitness of uninfected females and therefore *Wolbachia* infection is a potential mechanism for the development of reproductive isolation (Wade 2001). In addition to cytoplasmic incompatibility (Hoffman and Turelli, 1997), it has
been demonstrated that *Wolbachia* infection can alter the reproductive capacity of the arthropod host in a number of other ways including parthenogenesis induction (Stouthamer et al., 1993), feminisation of genetic males (Rousset et al., 1992), and son killing (Hurst et al., 1999). All of these increase the fitness of infected females at the expense of males.

Here we examine the genetic relationships between five putative species of Byturidae. Using molecular methods we indicate which species are most closely related. We also demonstrate that byturid beetles harbour multiple *Wolbachia* infections and we suggest these bacteria could be useful if developed as part of an integrated pest management scheme.

**Material and methods**

**Beetle material, amplification of beetle ribosomal DNA, amplification of beetle mitochondrial DNA, cloning and sequencing and data analysis**

For full details of molecular procedures, see Malloch et al., 2001.

**Amplification of Wolbachia wsp gene**

Bacterial *wsp* DNA was amplified using the following primers:- 81F (5’ TGG TCC AAT AAG TGA TGA AGA AAC 3’) and 691R (5’ AAA AAT TAA ACG CTA CTC CA 3’) (Braig et al., 1998). Ready to Go PCR beads (Amersham, Pharmacia) were used with the following conditions:- 1.5U of *Taq* polymerase, 10mM Tris-HCl, 50mM KCl, 3.5mM MgCl$_2$ and 200µM of each dNTP and 80ng of primers. A control tube containing only PCR components and no target DNA was included. The PCR cycling conditions were as follows:- 1min 94°C, 1min 55°C, 1min 72°C for 34 cycles; 1min 94°C, 1min 55°C, 5min 72°C for 1 cycle. A Techne PC-3 thermal cycler was used for all reactions (Scotlab, Lanark, Scotland, UK).

**Results and discussion**

**Phylogeny of raspberry beetles and other Byturidae (Coleoptera)**

A total of twenty-two ribosomal (ITS2) and thirteen mitochondrial plasmids (cytochrome oxidase) containing PCR products from byturid beetles (*B. tomentosus*, *B. unicolor*, *B. affinis*, *B. ochraceus* and *Xerasia grisescens*) were sequenced. Phylogenetic analyses were carried out on the data (see Malloch et al., 2001). The consensus ribosomal and mitochondrial phylogenetic trees were drawn to the same scale and are shown in Figure 1.

The byturid phylogenetic trees from mitochondrial DNA sequences are in close agreement with those from ribosomal sequences. The data clearly indicate that the two raspberry pest species *B. tomentosus* and *B. unicolor* are not the most closely related beetles in the byturid family. The results suggest that the Asian species *B. affinis* is more closely related to all the American *B. unicolor* biotypes than it is to the European species *B. ochraceus* or the palaeartic *B. tomentosus*. Asia appears to be the centre of diversity for the Byturidae with twelve out of sixteen known species present in this region. It seems likely that these beetles spread both west and east with the route east being colonized by ancestral *B. unicolor* possibly via the Bering land bridge (Malloch et al., 2001).

The molecular data also indicates that the *B. unicolor* specimens from Illinois, Washington State and Ohio are as distinct from each other as byturid species are from one another. *B. unicolor* was previously treated as four separate species: *B. unicolor*, *B. sordidus*, *B. rubi* and *B. bakeri* (Barber 1942). It is possible that the three populations studied here represent different species.
Ribosomal DNA sequence data for species in the genus Byturidae were used to construct a phylogenetic tree. The weevil species *Hypera punctata* (MIHP16980) was used to root the tree. The butterfly *Papilo glaucus* (AF044013) was used to root the mitochondrial tree. The trees were constructed using DNAML. A distance based method with bootstrapping was also used and it produced the same topology. The numbers above the branches indicate the bootstrap values out of 100. Oswed, Oczech, Ocamb=B. ochraceus; Tom=B. tomentosus; Affmor, AffFuku=B. affinis; Illinois=B. unicolor (Illinois); Wash=B. unicolor (Washington); Ohio=B. unicolor (Ohio); Xgris=Xerasia grisiscens

Figure 1. Phylogenetic trees of *Byturus* spp. based on rDNA and mitochondrial sequences
Molecular evidence for multiple infections of Wolbachia in byturid beetles

Factors affecting the evolution and divergence of insect species are complex, difficult to define and often not fully understood. Many parameters can influence the reduction or elimination of gene exchange and the intracellular bacterium Wolbachia is thought to have played a major role in reproductive isolation (Wade, 2001). We surveyed populations of B. tomentosus, B. affinis, B ochraceus and B. unicolor (Illinois) for Wolbachia infection using the Wolbachia surface protein (wsp) molecular marker (Braig et al., 1998). The results indicate that all byturid species tested harbour infection with Wolbachia. Natural populations of some byturid species support stable super-infections of three or four Wolbachia types. The results are summarised in Table 1 below:

Table 1 Number of Wolbachia variants harboured by byturid beetles

<table>
<thead>
<tr>
<th>Species</th>
<th>Wolbachia type</th>
<th>No. of Wolbachia Variants</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. affinis</td>
<td>wTom1</td>
<td>1</td>
</tr>
<tr>
<td>B. tomentosus</td>
<td>wTom1, wTom2</td>
<td>2</td>
</tr>
<tr>
<td>B. unicolor</td>
<td>wTom1, wTom2, wCol</td>
<td>3</td>
</tr>
<tr>
<td>B. ochraceus</td>
<td>wTom1A, wTom2A, wOch, wKue</td>
<td>4</td>
</tr>
</tbody>
</table>

Two wsp types (wTom1/A and wTom2/A) were present in most byturid species (except B. affinis, which harbours a single infection wTom1). It has yet to be conclusively demonstrated if the Wolbachia harboured by byturid beetles are associated with reproductive incompatibility but if they are, it is likely that they have contributed in driving speciation in this beetle family.

In addition it has been suggested that Wolbachia might be used to spread useful genes and agents, such as insect viruses, into natural insect populations and could therefore be useful in controlling and assaying insect pests (Sinkins et al., 1997). However, a full understanding of Wolbachia populations in diverse and natural situations is vital to any potential control strategy.

Acknowledgements

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References


Abstract

Molecular markers for the detection of predation by phytoseiid mites on strawberry

Nick Harvey, Jean Fitzgerald, Mike Solomon
Horticulture Research International, East Malling, Kent, ME19 6BJ, UK

Abstract: The study of predator prey interactions is an essential part of developing successful biocontrol strategies for pests. In strawberry plantations in SE England three species of phytoseiid mites are commonly found, and two species are commercially available for release. To investigate feeding preferences and interactions of these predators in the field situation it is necessary to develop markers that identify pest remains within the predator gut. In the past, prey specific isoenzymes or polyclonal/monoclonal antibodies have been used in such investigations. PCR techniques enable us to amplify DNA from prey individuals in the predator gut. This technique is very sensitive and specific. We have developed a set of primers that identify a range of pest mite species based purely on the length of the PCR product. These primers work well for detecting prey in particulate-feeding insect predators, but prey DNA appears to be rapidly digested in predatory mites. A series of primers have been designed that each amplify a different length of DNA from particular prey species. Work is ongoing to design a multiplex PCR system using these primers to determine prey preferences in the five species of phytoseiid mites in strawberry. This technique could also be used in other crop systems.
Abundance of blueberry bud mite (*Acalitus vaccinii*) in Michigan blueberries, and variation in infestation among common highbush blueberry varieties

Rufus Isaacs, Dariusz Gajek
Department of Entomology and Center for Integrated Plant Systems, Michigan State University, East Lansing, MI 48824, US
Research Institute of Pomology and Floriculture, Pomologiczna 18, 96-100 Skierniewice, Poland.

**Abstract**: The blueberry bud mite, *Acalitus vaccinii*, has not been reported previously in Michigan, but was found at six of twelve Michigan farms sampled during spring 2001. Four % of buds were infested with this species at the six infested sites. At this time of the year, buds were starting to swell, and adult mites were found feeding on the inner surfaces of the outer bud scales. Samples of four varieties collected in July 2001 from a highly-infested farm revealed inter-varietal differences in mite densities and in the level of plant response to infestation. A potential for biological control was identified; tydeid predatory mites were found in spring samples, with both tydeid and phytoseiid mites during summer samples. These results are discussed in relation to future research needs for understanding the biology and control of *A. vaccinii*.

**Key words**: Blueberry bud mite, Eriopyidae, Phytoseiidae, Tydeidae, *Vaccinium* spp.

**Introduction**

The blueberry bud mite, *Acalitus vaccinii*, is an eriophyid species infesting both highbush blueberry, *Vaccinium corymbosum*, and lowbush blueberry, *Vaccinium angustifolium* in North America. It was first reported by Fulton in 1940, and is typically a pest of blueberry in eastern North America. Keifer described this species in 1941 and found blueberry bud mites on many species of cultivated and wild blueberry. Early approaches toward its control were discussed by Bailey and Bourne (1946). Spring feeding damage extends from a reddening of bud tissue early in the season, to sufficient damage that leaf and fruit development is inhibited or prevented. Summer generations cause reduced vegetative growth that impacts the following year’s crop and in severe infestations, plant growth can be completely inhibited, which severely reduces yield. In North Carolina and Georgia blueberry plantations, there is active post-harvest management of this pest with acaricides.

Neunzing and Galletta (1977) sampled different blueberry species in Georgia and found that *V. angustifolium* and *V. corymbosum* were the most heavily infested, with 80 and 51 percent bud infestation on average, respectively. No blueberry species has been found that is fully resistant to the blueberry bud mite, though some varieties have been observed as free of mites in field collections (Neunzing and Galletta, 1977). Similar varietal variation was recently found in blackcurrant varieties to the blackcurrant bud mite, *Cecidophyopsis ribis* Westw., in which biochemical mechanisms were responsible for the different levels of resistance (Gajek et al., 1996).

Current recommendations for control of *A. vaccinii* in the United States rely on post-harvest application of endosulfan, the only acaricide registered for use in U.S. blueberry
production. This product has been shown to protect the activity of predatory mites feeding on *C. ribis* on blackcurrant (Gajek et al., 2000a). However, legislated re-evaluations of insecticide registrations in response to public safety concerns, and the risk of resistance development mandate the search for alternative approaches for control of blueberry bud mite.

Blueberry bud mite has not been reported from Michigan in the literature, even though this state is a leading producer of blueberries in North America. This study was conducted to determine whether blueberry bud mite is present in Michigan, and if so, what densities of infestation are present, and what biological options growers may have for control of this potentially damaging pest.

**Material and methods**

*Survey of blueberry bud mite*

In April 2001, twenty blueberry shoots (20 cm length) were randomly collected from twelve fields at commercial blueberry farms in SW Michigan. At this time, buds were starting vegetative growth, but no green leaves had emerged. Shoots were transported to the laboratory and examined for the presence of blueberry bud mite under a dissecting microscope at approximately 60 x magnification. The proportion of infested buds was calculated.

*Varietal susceptibility*

In July 2001, a farm in Grand Junction, Michigan, was identified with extreme symptoms of damage from *A. vaccinii* in some areas. To determine whether there was any variation in susceptibility to this pest between varieties, samples were taken from a field that contained Jersey, Bluecrop, Rubel, and Burlington varieties. The upper 20 cm of foliage was collected from one branch of each of ten randomly-selected plants of each variety, except for Rubel that was sampled in two separate areas. All samples were from an area less than 100 m². Collected shoots were placed in a cooler and transported to the laboratory, where the degree of blueberry bud mite infestation was determined. On each shoot, each new bud and the new leaves were assessed to determine the number of mites present. During sampling, predatory mites were counted and collected for identification.

**Results and discussion**

*Bud mite abundance*

Mites were detected in half of the fields sampled, with positive samples discovered in each of the major blueberry growing regions of SW Michigan. At one site, 6.9 % of the buds were infested, but in general the infestation of blueberry bud mite was low at this time (see Table 1). When buds were sampled in the spring, mites were most often detected on the inner surface of the outer bud scales. When found, between 1 and 50 mites were detected in a single bud. Characteristic raised and reddened tissue was observed around bud feeding sites.

Pesticide use is also likely to have contributed to the densities of *A. vaccinii* described, although growers have not applied insecticides specifically for this pest in Michigan. Damage symptoms caused by *A. vaccinii* are similar to those caused by winter injury, and this, along with the mite’s size, has contributed to the low awareness of this species as a potential pest. Although damage is not clearly identifiable early in the year, bud sampling in the spring could be used to identify mite infestation before the clear symptoms of reduced growth and fruit set are evident.
**Varietal susceptibility**

All four varieties sampled from the heavily infested site were infested with blueberry bud mite, and the degree of infestation was significantly different between varieties (Table 2). As many as 50.4% of the buds were infested in one of the Burlington samples, even though this variety showed relatively low damage symptoms. Rubel was the most affected variety, with stunted growth and poor fruit set, but it also showed a high degree of infestation, with 28.9 and 35.4% bud infestation with *A. vaccinii*, compared to less than 15% on Bluecrop and Jersey. In addition, the number of mites per bud was greatest in these two varieties, with more than one mite per bud on average. Calculation of the infestation intensity, derived from the percent bud infestation and the number of mites/bud, showed that Burlington and Rubel were highly infested, whereas Bluecrop and Jersey had relatively low infestations (Table 2). Although not specifically recorded, the visible symptoms of damage were most pronounced in Rubel, followed by Jersey, Bluecrop, and Burlington (which has no signs of reduced vegetative growth, although infestation intensity was the highest, suggesting that infestation intensity and damage intensity were not correlated).

Plant variety is an important factor that has been described previously as influencing the density of blueberry bud mite (Neunzing and Galletta, 1977), although no completely resistant variety has been found. Further investigation of the relationship between mite density and damage symptoms, and the mechanisms underlying resistance, could be used to develop blueberry varieties that reduce the likelihood of losing growth and yield from infestation by *A. vaccinii*. Blackcurrant varieties from a breeding program in Poland have been described that are resistant to the blackcurrant bud mite (*Cecidophyopsis ribis* Westw.) (Gajek et al., 2000b), and a similar program may be possible for developing blueberry resistance to *A. vaccinii*. However, other varietal characteristics are typically more important for plant selection by blueberry growers, and *A. vaccinii* is not as critical to effective pest management in Michigan blueberries as *C. ribis* is to Polish blackcurrant production.

**Predatory mites**

Tydeid mites were collected from the farms visited in spring 2001, found at low densities between bud scales in close proximity to *A. vaccinii*. During summer sampling, phytoseiid and tydeid mites were collected from the infested collection site at which the varietal comparisons were made (above). All putative predatory mites were found in close proximity to colonies of *A. vaccinii*. At the time of writing, identifications of these species have not been completed, but will be reported in a future publication.

The importance of these mites for controlling *A. vaccinii* is unclear. Some species of the Tydeidae family have been reported as predators of eriophyid mites (Abou-Awad et al., 1999). Phytoseiid mites were also found closely associated with bud mites during the summer, and the role of phytoseiids in regulating pest mites is well known (Herbert and Sanford, 1969; Solomon, 1982; Schliesske, 1988; Kozlowski and Kozlowska, 1991).

A fungus parasite, *Hirsutella thompsonii*, has been reported that can reduce populations of *A. vaccinii* during the summer months (Baker and Neunzig, 1968). Considering the frequent rains in Michigan during the spring, the fungus may have a significant impact on this pest in Michigan.

This suite of natural enemies may ensure that *A. vaccinii* populations rarely become large enough to cause the entire loss of a field’s blueberry crop. However, at the highly infested site reported above, biocontrol activity was unable to prevent severe damage, and chemical control options are likely to remain an important tool to reduce the mite population below a level at which economic damage occurs.
Although legislated changes in endosulfan use patterns for US blueberry growers are yet to be decided, post-harvest or delayed-dormant timings for application of acaricides may be required to provide effective control. The period of mite migration from old buds to new ones seems to be the most effective time for acaricide applications, but the timing of this movement should be determined. Acaricides are typically applied to blueberry plants post-harvest in southern states to control *A. vaccinii* (Sorenson, 1984), but the slower annual phenology of blueberry in more temperate climates may provide alternative timings for control, such as when the buds are opening to expose the overwintering females in the spring, but before flowering has occurred.

Table 1. Occurrence and infestation intensity of adult *Acalitus vaccinii* in Michigan blueberry plantings during spring 2001.

<table>
<thead>
<tr>
<th>Farm</th>
<th>Location</th>
<th>Variety</th>
<th>% bud infestation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Bridgeman</td>
<td>South Haven</td>
<td>Bluecrop</td>
<td>0.0</td>
</tr>
<tr>
<td>2 South Haven</td>
<td>South Haven</td>
<td>Jersey</td>
<td>6.9</td>
</tr>
<tr>
<td>3 South Haven</td>
<td>South Haven</td>
<td>Bluecrop</td>
<td>6.4</td>
</tr>
<tr>
<td>4 Bangor</td>
<td>South Haven</td>
<td>Jersey</td>
<td>0.0</td>
</tr>
<tr>
<td>5 Paw Paw</td>
<td>South Haven</td>
<td>Bluecrop</td>
<td>0.0</td>
</tr>
<tr>
<td>6 Fennville</td>
<td>South Haven</td>
<td>Rubel</td>
<td>0.2</td>
</tr>
<tr>
<td>7 Holland</td>
<td>South Haven</td>
<td>Elliott</td>
<td>5.2</td>
</tr>
<tr>
<td>8 Holland</td>
<td>South Haven</td>
<td>Blue Jay</td>
<td>0.0</td>
</tr>
<tr>
<td>9 Holland</td>
<td>South Haven</td>
<td>Blue Ray</td>
<td>0.6</td>
</tr>
<tr>
<td>10 Holland</td>
<td>South Haven</td>
<td>Duke</td>
<td>0.0</td>
</tr>
<tr>
<td>11 Holland</td>
<td>South Haven</td>
<td>Bluecrop</td>
<td>4.9</td>
</tr>
<tr>
<td>12 Holland</td>
<td>South Haven</td>
<td>Elliott</td>
<td>0.0</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td>2.02</td>
</tr>
<tr>
<td>Average of infested sites</td>
<td></td>
<td></td>
<td>4.03</td>
</tr>
</tbody>
</table>

Table 2. Infestation levels of *Acalitus vaccinii* on different highbush blueberry varieties in a plantation in Grand Junction, MI. Samples were taken on July 13, 2001.

<table>
<thead>
<tr>
<th>Variety</th>
<th>No. buds surveyed</th>
<th>No. buds with mites</th>
<th>% Buds with mites</th>
<th>Total number of mites</th>
<th>Average mites/bud</th>
<th>Infestation intensity *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue Crop</td>
<td>112</td>
<td>16</td>
<td>14.3</td>
<td>32</td>
<td>0.3</td>
<td>4.0</td>
</tr>
<tr>
<td>Jersey</td>
<td>111</td>
<td>9</td>
<td>8.1</td>
<td>8</td>
<td>0.07</td>
<td>0.5</td>
</tr>
<tr>
<td>Burlington</td>
<td>115</td>
<td>58</td>
<td>50.4</td>
<td>206</td>
<td>1.8</td>
<td>90.0</td>
</tr>
<tr>
<td>Rubel Site I</td>
<td>214</td>
<td>62</td>
<td>28.9</td>
<td>251</td>
<td>1.1</td>
<td>34.0</td>
</tr>
<tr>
<td>Rubel Site II</td>
<td>212</td>
<td>75</td>
<td>35.4</td>
<td>346</td>
<td>1.6</td>
<td>56.0</td>
</tr>
</tbody>
</table>

*Intensity of infestation = (% buds with mites x average mites/bud)
A clearer understanding of the biology and ecology of *A. vaccinii* in Michigan is essential for the development of optimal control programs in this major blueberry production region. The broad geographic range of *A. vaccinii* within Michigan found in this survey and the degree of damage associated with its presence indicates that this pest requires active monitoring. A management program is needed that provides a standard method for sampling, decision-making, and effective chemical control options that retain the activity of biological control agents.

**Acknowledgements**

Our thanks to the Michigan blueberry growers for allowing sample collection from their farms, and to Mr. Dave Trinka of Michigan Blueberry Growers Association for providing information on potential collection sites. This research was conducted while Dr. Gajek was a visiting scholar at Michigan State University during 2001, under a fellowship from the Organization for Economic Cooperation and Development.

**References**


Damage caused by blackberry mite (*Acalitus essigi* Hassan) and the role of natural biological control agents in integrated blackberry production system in Hungary

Gabriella Szendrey¹, Zoltán Ilovai², Zoltán Lucza²

¹ Plant Protection and Soil Conservation Service of Heves County, H-1300 Eger, Szövetkezet u. 6., Hungary
² Central Service for Plant Protection and Soil Conservation, H-1118 Budapest, Budaörsi út 141-145, Hungary

Abstract: In Hungary the blackberry mite *Acalitus essigi* Hassan is considered one of the most noxious pests of blackberry. The damage caused by mites to the fruits seriously reduces their marketability. Therefore the control of the pest has to be built on prevention. In order to define the optimal time of treatments against *A. essigi* seasonal changes of blackberry mite population have been studied. Also bud samples were collected to identify the natural enemies of mite, i.e. parasitoids and predators. The beneficial elements of fauna were then involved into laboratory and field experiments. The aim was to determine the side effect of pesticides considered less harmful to beneficials. The following active ingredients have been tested: paraffin oil, S-polysulphide+paraffin combination, Ca-polysulphide, flufenzin, fenpyroximate and pyridaben. The population-dynamic studies showed that there were two periods crucial for a successful control: 1) end of winter dormancy before the mites lay eggs and, 2) from bud stage till flowering when the mites are migrating. The agro-ecosystem of blackberry plantations proved to be rich in beneficial fauna. Acarophagous mites from families Phytoseiidae, Tydeidae and Stigmaeidae have been found to be prevalent. Also other unique species from families, Cecidomyidae, Coccinellidae, Anthocoridae, Triptidae, Aeolothripidae and Philaeothripidae play important role in reduction of the density of blackberry mites.

Key words: *Acalitus essigi*, acarophagous mites, beneficial fauna, side-effect of pesticides, integrated blackberry protection system

Introduction

In Hungary, production of thornless blackberry started in the 1980s and at present the total acreage is 600 hectares. The major varieties grown are Thornfree and Dirksen Thornless. In new plantations, the variety Loch Ness is increasing in importance. Growing is made in private gardens, family farms and holdings belonging to production systems.

With the increase of blackberry growing area, several phytosanitary problems have been caused by the attacks of blackberry mites. The first Hungarian report on the distribution of and damages by *Acalitus essigi* was published by Kollányi and Bakcsa in 1984. The first infested material was forwarded to our institute in September 1991. Our objective, therefore, has been to make overall surveys on blackberry mites in the blackberry plantations in Heves county. We have studied the beneficial living organisms associated to the species as well as the possibilities of environmental-friendly management.

Materials and methods

The survey on the spread of blackberry mite started in 1992 in seven plantations under the supervision of the Plant Health and Soil Conservation Station of Heves County. Observations
were made twice a year: a) in dormancy and b) during fruit ripening. During these dates, the number of the beneficial organisms was also recorded. The morphology, biology and damage caused by the blackberry mite together with the occurrence of the associated mite predators were studied in the variety Thornfree. The test material was taken weekly and examined in the laboratory from mid-March to green bud stage. The change in mite numbers and behaviour was investigated under a stereo-microscope on the twigs every 3-4-days. After the appearance of the buds, samples were taken to the laboratory twice a week. The objective was to obtain as many reliable data on this species as possible. Study on the way of life was necessary because we wanted to know the optimal timing of treatments.

In order to choose less toxic active ingredients to the beneficial fauna, we carried out trials with the following formulations: paraffin oil, Vaseline oil, polysulphide sulphur, Ca-polysulphide, flufenzin, fenpyroximate and pyridaben (Table 1). The effect was assessed by visual examination at appearance of damage symptoms on 20 × 5 fruits randomly selected. The evaluations were carried out in third decade of July, and in first decade of August. Efficiency was determined used by Abbott formula.

Table 1. Active ingredients applied to control blackberry mites:

<table>
<thead>
<tr>
<th>Year of the trial</th>
<th>Active ingredients applied</th>
<th>Growth stage of blackberry</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Treatment 1</td>
</tr>
<tr>
<td>1997</td>
<td>Flufenzin 0,5 l/ha</td>
<td>10 cm shoot length</td>
</tr>
<tr>
<td></td>
<td>Pyridaben 1,0 kg/ha</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Paraffin oil +</td>
<td>Opening of bud</td>
</tr>
<tr>
<td></td>
<td>Atplus 300 F 1 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Calcium-polysulphide 2 %</td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>Flufenzin 0,5 l/ha</td>
<td>Opening of bud</td>
</tr>
<tr>
<td></td>
<td>Pyridaben 1,0 kg/ha</td>
<td>Budding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Beginning of flowering</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Opening of bud</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Opening of bud</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Opening of bud</td>
</tr>
<tr>
<td>2000</td>
<td>Fenpyroximate 1,0 l/ha</td>
<td>Budding</td>
</tr>
<tr>
<td></td>
<td>Bromopropylate 1,5 l/ha</td>
<td>Budding</td>
</tr>
<tr>
<td>2001</td>
<td>Fenpyroximate 1,4 l/ha</td>
<td>Budding</td>
</tr>
<tr>
<td></td>
<td>Bromopropylate 1,5 l/ha</td>
<td></td>
</tr>
</tbody>
</table>

Results and consequences

The blackberry mite (*Acalitus essigi*) is a pest that occurs permanently in the plantations under study. It causes damage of economic importance. Its control is difficult because of its tiny size and “hiding” way of life.
During the surveys made in the dormancy of the host-plants, only small populations of overwintering females were observed. The significant damage observed at fruit ripening confirmed, however, that even this relatively low pest number should not be underestimated. The predatory mites associated with blackberry mite could also be detected during overwintering. Species belonging to the families of Tydeidae and the Phytoseiidae were more frequently found. Their presence in the plantations obliged us to make environmental-friendly management.

During the fruit ripening, we recorded damage symptoms. Damage caused by mites is expressed in fruit malformation, abnormal colouring and, in more severe cases, in losses of weight. The fruits infested by blackberry mites are harder and have less taste than the healthy berries. They are not suitable for fresh consumption or for export, and their marketable value is greatly reduced. The damage cannot be confounded with the uneven ripening induced by a physiological process. At that time the drupelets near the peduncles are ripe (black) and the top of the berry is still not (red). If the irregular, mosaic-like ripening appears on the base of the berry, infestation by mites can be suspected. Another common form of damage is caused by ultra-violet radiation during periods of intense sunlight. The fruits become lighter in colour and the drupelets are soft. It is important to distinguish this type of damage from that caused by mites. The most severe damage by mites was observed at ripening of the variety Thornfree in 1997 and 2001. Then, on week 3 after the beginning of ripening the infestation level was 60-80 % in the untreated part of the plantation.

During fruit ripening, more mite predators were detected: Typhlodromus pyri Scheuten, Euseius finlandicus Oudemans, Amblyseius andersoni Chant, Kampimodromus aberrans Oudemans, Zetzellia mali Ewing, Orius sp., Aeolothrips intermedius Bagnall, Haplothrips subtilissimus Haliday, Stethorus punctillum Weise, Oligota flavicornis Boisd., Cecidomyidae. Some of them may be associated with Tetranychus urticae observed on the leaves.

Observations concerning the biology of blackberry mite
The blackberry mite belongs to the family of Eriophyidae. It has four legs and a longitudinal whitish transparent body. Length is 120-180 µm. The number of dorsal and ventral annuli is similar. The developed female adults overwinter under the bud scales, at the base of the petiole covered by the buds and among the berry drupelets remaining on the plants. If the temperature is constantly above 0 °C, mites start oviposition. Eggs are laid under the bud scales, later to the bases of the leaves, then to the carpels on the receptacles. Even later, eggs are laid to the surface of the stony drupes in contact with each other. Bud damage is, however, not frequent. But in those cases buds are nevertheless attacked, they die. Mite migration starts at the time of shoot development and mites move to the upper floors during the development of the host plants. At flowering they cover the blossoms and cause, by sucking the fruits, the severest damage. Their reproduction is rapid with generations overlapping each other. Species of the families Tydeidae and Phytoseiidae follow the movement of the blackberry mite thus reducing its population density.

It was concluded from the trial results that the treatment carried out at bud-burst reduced the population density of Acalitus essigi, mitigating its increase during the season. The most effective treatments were applied at opening of bud + budding + early flowering (3×). Spraying at budding + early flowering also provided good efficacy. The results are shown in graphs (Figure 1-4).
Proposed pest management in the integrated production

- Cultural control: healthy propagating materials free from blackberry mites shall be planted. Early varieties shall be preferably used. Prior to planting, wild blackberry shall be removed from the vicinity of the plantation. After harvest, no fruits shall be left on the bushes. Ripen, infested twigs shall be removed and burnt. No excess of fertilizers shall be applied.

- Biological control: the regulating capacity of predatory mites shall be used. When choosing the pesticides, their side-effect on the beneficial fauna shall be considered.

- Chemical control: it shall be based on forecasting. The population status shall be surveyed in dormancy.
**Timing of the necessary treatments:**
1. At the end of winter or at opening of buds, wash-off sprayings are recommended (to reduce population!): paraffin oil, Vaseline oil, polysulphide sulphur, Ca-polysulphide, flufenzin.
2. During migration: by spraying the following active ingredients at bud stage + early flowering, establishment of the mites is prevented on the receptacle: paraffin oil, polysulphide sulphur, Ca-polysulphide, flufenzin, fenpyroximate and pyridaben.

![1998 Efficiency Chart](image1)

**Figure 3.**

![2001 Efficiency Chart](image2)

**Figure 4**
References

A possible resurgence of minor fungal diseases in *Rubus* caused by a reduction in fungicide use

Brian Williamson
*Scottish Crop Research Institute, Invergowrie, Dundee DD2 5DA, United Kingdom*

**Abstract:** Production of red raspberry (*Rubus idaeus*) and other *Rubus* cane fruits relies currently in some areas on repeated applications of fungicides to ensure freedom from major diseases, such as grey mould (*Botrytis cinerea*). With pressure from consumers, large retail outlets and processors for a reduction in fungicide use, growers face some difficult decisions about how best to control diseases, but simultaneously maintain high fruit quality and profitability. The recent expansion of covered cropping and out-of-season production to provide fresh berries when prices are high has also increased the risk of attack by some fungal diseases that previously were of little concern. The expansion of new cane fruit industries in southern countries of Europe, Asia and elsewhere will inevitably expose these industries to the possible import of well-known pathogens with planting material. It may also lead to epidemics of novel pathogens and pests of raspberries and blackberries arising from local reservoirs of inoculum in wild *Rubus* spp.

Being long-lived woody perennials with a biennial cane habit, raspberries and other cane fruits tend to accumulate fungal inoculum as plantations age. Unless high quality, disease-free stocks are used for crop establishment and rigorous control measures are imposed continuously from planting, diseases such as cane spot (*Elsinoe veneta*), spur blight (*Didymella applanata*), cane blight (*Leptosphaeria coniothyrium*), raspberry yellow rust (*Phragmidium rubi-idaei*) and powdery mildew (*Sphaerotheca macularis*) can become serious threats to production in some cultivars, in addition to the constant risk of grey mould. Cultural methods that reduce the risk of fungal diseases and optimise the benefit offered by restricted fungicide application will be discussed within the context of integrated pest management.

**Key words:** integrated pest management, raspberry, blackberry, hybrid berry, *Botrytis cinerea*, fungicides, *Elsinoe veneta*, *Didymella applanata*

**Introduction**

Since the introduction of modern synthetic fungicides in the 1960s, field-grown red raspberries (*Rubus idaeus*) and other *Rubus* cane fruits have been sprayed routinely for control of grey mould (*Botrytis cinerea*) during the blossom period to reduce the substantial losses that grey mould causes during and after harvest. The early work in strawberries by Powelson (1960) and then work on strawberries and raspberries by Jarvis (1962) had shown that this pathogen infects flowers to establish a quiescent infection; the 4-6 spray programmes were introduced largely on the basis of their work. Subsequent detailed epidemiological studies in conjunction with spray trials at the Scottish Crop Research Institute (SCRI) (Dashwood and Fox, 1988) validated these early findings. More recent work showed that conidia of *B. cinerea* germinate in the stigmatic fluid in newly opened flowers to infect the styles in the complete absence of water droplets (McNicol et al., 1985; Williamson et al., 1987).

The heavy reliance on pesticides for protection of fruit crops is now being questioned increasingly because of public concern about unintended side effects of these treatments on
beneficial insects, fish, birds and claimed effects of pesticides on the health of consumers and those living in the countryside. Strong legislation is in place in Europe, North America and other production areas to ensure that pesticides for use in agriculture are not approved unless the formulations are demonstrably safe to the crop, farm workers, the public and the environment. Nevertheless, there is an increasing market for fruits produced by 'organic' production systems that guarantee that no synthetic pesticides were used. As retail outlets strive to satisfy consumer demand and promote sales of 'organic' fruits as a niche market there is also the realisation that some crops are especially difficult to produce without very high standards of crop protection. Raspberries should be considered in this category. However, the introduction of Integrated Pest Management (IPM) for raspberry production systems represents a scientifically based approach to disease control that offers opportunities for reduced fungicide usage without reduced yield and fruit quality.

In this paper I outline some of the opportunities that exist for reduced fungicide usage in raspberries, blackberries and other cane fruits against a background of a rapidly changing soft fruit industry that is attempting to produce the highest quality fruit with the minimum of fungicide input. However, to implement such a cultivation system it is essential to have a more complete understanding of the biology of the numerous fungal pathogens that threaten raspberry production and to realise that many of the diseases currently of minor importance are likely to rise to prominence if routine spraying against \textit{B. cinerea} is no longer deemed acceptable for some markets.

**Trends in modern raspberry production**

Raspberry and blackberry breeding programmes have successfully released new cultivars in the last 20 years that flower and fruit earlier in summer than previously possible to attract higher fruit prices than traditional summer-fruiting genotypes. Nevertheless, despite these advances there has been a displacement of field-grown raspberries that ripen in natural season by high-cost systems that enable out-of-season production under plastic or in glasshouses using long cane techniques (Carew et al., 2000) because they attract the highest prices. Covered production is currently favoured because hand picking of fruit is not interrupted by periods of rain. Covered production has increased the importance of raspberry yellow rust (\textit{Phragmidium rubi-idaei}), powdery mildew (\textit{Sphaerotheca macularis}) and cladosporium mould due to increased temperature, relative humidity and inadequate ventilation. Although micropropagation has eradicated phytophthora root rot and many virus diseases from elite germplasm, at the weaning stage blackberry and hybridberry stocks are highly susceptible to downy mildew (\textit{Peronospora rubi} = \textit{P. sparsa}) and the disease is now widespread (Williamson et al., 1997) (see Table 1).

Other sectors of the raspberry industry have attempted to reduce costs of main season production by mechanised harvesting. With improved harvester design (Williamson and Ramsay, 1984), the introduction of mechanised harvesting in Scotland has been successful, despite the frequency of rain-showers during harvest that favour cane blight (\textit{Leptosphaeria coniothyrium}), but the fruit is only suitable for freezing and processing and therefore attracts lower prices and is in direct competition with imported frozen berries from other areas of the world where labour costs are lower.

As a minor crop on a world scale, raspberries and other \textit{Rubus} cane fruits do not have consideration by agrochemical companies developing new active ingredients and formulations because the market is too small. Only when fungicides for major crops have a proven track record will companies begin to consider their use on minor crops, but because the cost of registration of new chemicals is high, even effective chemicals often do not
become formally approved for use. Similarly, older chemicals are under continuous review by registration authorities so that modern toxicological standards are applied and the environmental issues re-examined in detail. Again, the costs involved in these procedures are substantial and as a result many older chemicals have been withdrawn for commercial reasons or on toxicological grounds. With fewer fungicides available for use, decisions about how best to protect minor crops are increasingly difficult to make.

Table 1. Some minor fungi affecting *Rubus* cane fruits in Europe

<table>
<thead>
<tr>
<th>Fungus</th>
<th>Disease caused</th>
<th>Main host*</th>
<th>Target tissue</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Elsinoe veneta</em></td>
<td>cane spot</td>
<td>R/B/H</td>
<td>Young green tissue</td>
</tr>
<tr>
<td><em>Didymella applanata</em></td>
<td>spur blight</td>
<td>R</td>
<td>Mature leaves</td>
</tr>
<tr>
<td><em>Leptosphaeria coniothyrium</em></td>
<td>cane blight</td>
<td>R/B/H</td>
<td>Wounded young canes</td>
</tr>
<tr>
<td><em>Sphaerotheca macularis</em></td>
<td>powdery mildew</td>
<td>R</td>
<td>Young green tissue</td>
</tr>
<tr>
<td><em>Peronospora rubi (= P. sparsa?)</em></td>
<td>downy mildew</td>
<td>B/H</td>
<td>Young green tissue</td>
</tr>
<tr>
<td><em>Phragmidium rubi-idaei</em></td>
<td>raspberry yellow rust</td>
<td>R</td>
<td>Young leaves, pedicels, sepals</td>
</tr>
<tr>
<td><em>Phragmidium violaceum</em></td>
<td>blackberry rust</td>
<td>B</td>
<td>Young leaves</td>
</tr>
<tr>
<td><em>Hapalosphaeria deformans</em></td>
<td>stamen blight</td>
<td>R/B/H</td>
<td>Axillary buds, flower promordia</td>
</tr>
<tr>
<td><em>Septocyta ruborum</em></td>
<td>purple blotch</td>
<td>B</td>
<td>Young canes</td>
</tr>
</tbody>
</table>

*R= raspberry; B= blackberry; H= hybridberry

The introduction of Maximum Residue Levels (MRLs) to protect the consumer and the environment from excessive application of single fungicides has had a major impact on the approaches made by retail outlets towards fruit producers. The concept of 'traceability to source' for each fruit consignment offered for sale now should ensure that consumers are protected from excessive spray applications. In addition, the introduction of formal justification before use of a chemical is a growing trend after its introduction in the US for some crops.

The retail market usually dictates the cultivar that is to be grown for their outlet, often with little regard for the relative disease susceptibility of that cultivar. There are several examples of cultivars showing strong resistance to different fungal diseases (Williamson and Jennings, 1992), but unfortunately there is no single cultivar carrying resistance to all diseases! Retailers and consumers also expect the fruits to be large, blemish-free and free of all visible residues. Little progress in 50 years has been made in breeding for resistance to grey mould (Williamson et al., 1993). As a result there have been attempts to introduce novel disease resistance by gene transfer technologies using a raspberry PGIP gene (Ramanathan et al., 1997; Brennan et al., 1999). Public criticism of this approach has made progress by these methods difficult to support, however, even though the concept has been demonstrated successfully by use of a similar gene in tomatoes (Powell et al., 2000).
Sources of aerial fungal pathogens affecting *Rubus* cane fruits

The most important source of fungal pathogens in the early years of a raspberry plantation is the cane material raised in a 'spawn bed' or cane nursery. Even in countries adhering to the EPPO Standards on Phytosanitary Measures - 'Schemes for the Production of Healthy Plants for Planting (PM4/10/(1))', the nursery beds are given only two visual inspections of above-ground plant parts during a growing season. It is therefore possible that low levels of fungal disease in such stocks could go undetected and the pathogen be introduced at planting.

Once a plantation is established, in conditions favourable for infection and sporulation, the pathogen will multiply and disperse from original foci of infection to place the entire plantation and surrounding fields at risk. *Botrytis cinerea* is a ubiquitous fungus and it survives in dead and dying plant tissues of all plants. It can therefore be carried from neighbouring fields from other crops (e.g. cabbages, lettuces). However, many other pathogens of *Rubus* are specific for this genus, or even for one species, and survive on the overwintering 1-year-old maturing primocanes and sporulate in spring on the fruiting canes. Cultural practices should take account of the fact that many of these pathogens also survive on pieces of dead canes, foliage and even in the soil of a raspberry plantation.

In most production areas for *Rubus* cane fruits there are wild members of the Rosaceae growing in adjacent woodlands and hedgerows. Although these plants may represent an important reservoir for beneficial insects or mites, they also are an important source of fungal inoculum. With current attitudes about the importance of preserving hedgerows and unplanted fields as refuge areas for wild birds, butterflies and other insects it is not acceptable to eradicate these sources of fungal pathogens.

Types of airborne fungal inoculum

Fungal propagules are diverse amongst the pathogens infecting *Rubus*, and even within a single fungal species there may be two-to-five different spore types, each with its own dispersal mechanism that replies on different environmental conditions to survive and infect the host plant, sometimes by different pathways. Some spore types are evolved to disperse and infect in air at high relative humidity (rusts, powdery mildews and downy mildews), others have both splash-dispersed conidiospores and hydrostatic dispersal of ascospores at high humidity (cane spot, spur blight, cane blight) (see Ellis et al., 1991). *B. cinerea* is unusual in that it can be dispersed by dry air, by splash dispersal and by insect dispersal. The conidia can germinate and hyphae infect petals in water droplets, and also without water droplets at relative humidities above 93% (Williamson et al., 1995); conidia germinate in the stigmatic fluid on the flower and hyphae colonise the transmitting tissue of the style (McNicol et al., 1985).

The relative importance of each spore type depends on the time of spore discharge, the susceptibility of the target host tissue and the prevailing weather in the crop. Each of these three aspects is amenable to modification by the fruit grower to reduce the impact of a single pathogen, but several pathogens with different characteristics affect *Rubus* crops and some compromise is inevitable.

Target infection sites and times of infection for various minor fungal pathogens

Raspberry pathogens are specialised to infect only certain parts of the plant at a critical stage of development, and only under favourable environmental conditions. For example, germinating conidia of *Elsinoe veneta* can only penetrate the epidermis of very immature
green tissues before the cuticle is fully mature and before the cork layers of canes have differentiated (Williamson and McNicol, 1989; Williamson et al., 1989) (see Table 2). *Leptosphaeria coniothyrium* conidia infect only wounded young primocanes in the harvest period (Williamson and Hargreaves, 1978). Newly opened flowers are at high risk for *B. cinerea*, *Peronospora rubi*, and *E. veneta*, whereas mature-to-senescent leaves are the main target for conidiospores of *Didymella applanata* and also for *B. cinerea*, two pathogens that occupy the same ecological niche on primocanes leading to suppression of axillary buds ('bud failure') in the fruiting year (Williamson and Jennings, 1986). *Septocyta ruborum* infects unwounded blackberry primocanes.

Table 2. Symptoms and crop damage caused by minor fungal diseases of *Rubus*

<table>
<thead>
<tr>
<th>Fungus</th>
<th>Symptoms</th>
<th>Crop damage</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Elsinoe veneta</em></td>
<td>Deep cane cankers, leaf spots, misshapen fruits</td>
<td>Dead canes, defoliation, unmarketable fruit</td>
</tr>
<tr>
<td><em>Didymella applanata</em></td>
<td>Lesions on mature leaves, dark cane lesions and bark silerving</td>
<td>Dwarfed axillary buds, suppression of lateral shots</td>
</tr>
<tr>
<td><em>Leptosphaeria coniothyrium</em></td>
<td>Brown vascular lesions spreading from wounds, blackish spore masses on cane</td>
<td>Bud failure, lateral wilt and cane death (good primocane growth)</td>
</tr>
<tr>
<td><em>Sphaerotheca macularis</em></td>
<td>White powdery masses on leaves (often up-turned margins) and green drupelets</td>
<td>Unmarketable misshapen small fruits, plant vigour reduced, premature defoliation</td>
</tr>
<tr>
<td><em>Peronospora rubi</em> (= <em>P. sparsa?</em>)</td>
<td>Irregular brown lesion on leaves, uneven swelling and ripening of drupelets</td>
<td>Infection at blossom causes misshapen berries, premature fruit abscission. Fungus can become systemic</td>
</tr>
<tr>
<td><em>Phragmidium rubi-idaei</em></td>
<td>Five spore types all on raspberry; yellow or black pustules on leaves, sepals and pedicels</td>
<td>Premature defoliation in late summer leading to loss of winter-hardiness and loss of vigour</td>
</tr>
<tr>
<td><em>Phragmidium violaceum</em></td>
<td>As above</td>
<td>As above</td>
</tr>
<tr>
<td><em>Hapalosphaeria deformans</em></td>
<td>White powdery masses originating from stamens in open flowers</td>
<td>Fruits often misshapen and drupelets lack cohesion</td>
</tr>
<tr>
<td><em>Septocyta ruborum</em></td>
<td>Dark brown lesions with reddish margins on canes</td>
<td>Flower buds and leaves on lateral shoots arising from infected nodes die becoming barren and desiccated</td>
</tr>
</tbody>
</table>

'Minor' fungi can be destructive if uncontrolled

*B. cinerea* is the only aerial plant pathogen to be controlled routinely by fungicides in the UK and elsewhere in Europe. Broad-spectrum contact chemicals applied four-to-six times at 7- to 10-day intervals during blossom have also given satisfactory control of several minor fungal
pathogens when applied at high volume and directed to canes. For example, dichlofluanid and
tolyllfluand have given useful control of *E. veneta*, *D. applanata* and *H. deformans* and
reduced attacks by *S. macularis*. Outbreaks of *E. veneta* have occurred when more botrytis-
specific dicarboximide fungicides, such as vinclozolin, have been used in the past, or when
resistance in the pathogen has arisen due to use of the MBC fungicide carbendazim in
preference to dichlofluanid (Munro et al., 1988). The new botrytis fungicides approved for
use in Europe (fenhexamid, pyrimethanil, azoxystrob in) still have not been evaluated for
efficacy against other cane, foliage and fruit diseases of *Rubus*. Any management system that
reduces or removes existing botrytis spray programmes will need to take account of the wider
aspects of disease control and the conditions under which infection occurs.

**Opportunities for Integrated Pest Management**

High standards of crop husbandry are always essential in long-lived woody perennial crops
because fungal inoculum increases with plantation age and crop rotations are extended.
Healthy planting stocks are of paramount importance to avoid introduction and spread of
diseases which, once established, cannot be removed and of which some survive in soils for
years (e.g. *P. rubi*). The removal of inoculum and the creation of an open crop canopy to
hasten drying after rain, dew or irrigation is imperative. Therefore, removal of old fruiting
canes immediately after harvest, winter pruning to the optimum cane density, *removal to soil
level* and burning of evidently diseased canes is important, especially for *L. coniothyrium* that
survives on dead cane stubs at the base of the plant where they damage primocanes in the
infection court (Williamson and Hargreaves, 1981). Avoidance of damage to primocanes
during harvest will avoid serious cane blight, so that careful hoeing and harvesting is
essential. Over-head irrigation should be avoided and plastic tunnels should be adequately
ventilated to reduce the relative humidity that favours several pathogens that disperse spores
and infect in humid atmospheres. Efficient control of weeds is also necessary because they
provide a humid environment around the base of canes that favours fungal infection,
especially *P. rubi-idaei* and *E. veneta* early in spring and *D. applanata* and *B. cinerea*
attacking senescent leaves on canes low in the canopy before and after harvest. Moderate
application of nitrogen fertiliser will avoid serious infection by *D. applanata* (Goode, 1970).
Crop 'scouting' to identify outbreaks of pathogens in the crop can indicate the need for early
fungicide treatment (e.g. against *E. veneta*) or introduction of an eradication policy if the
disease is not locally endemic.

Some of the best opportunities for reduction in fungicide use, especially in open-field
cultivation, arise from cane management systems introduced originally in the 1970s that
involve re-phasing of primocane growth with the result that the life cycles of pathogens and
pests are disrupted. The removal of the first flush of primocanes (cane vigour control) in
vigorous cultivars effectively reduced *D. applanata*, *B. cinerea*, *P. rubi-idaei*, *L. coniothyrium*
and the raspberry cane midge *Resseliella theobaldi* (Williamson et al., 1979). The toxic
herbicide dinoseb-in-oil previously used for cane management was subsequently replaced by
sodium monochloroacetate. Biennial cropping that involves the complete removal of
primocane growth in one year, and by total removal of fruiting canes in the following year, is
effective in breaking life cycles and reducing the impact of the same pathogens and pests
when applied in large blocks (Anthony et al., 1987) and has the advantage that complete
mechanisation is possible with reduced costs. However, in my view, complete avoidance of
fungicides in raspberries destined for the high value markets is a difficult objective with
current cultivars and commercial constraints.
Acknowledgements

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References


Effect of plant spacing on yield and incidence of *Botrytis cinerea* Pers. in strawberry

Holger Daugaard

*Danish Institute of Agricultural Sciences, Department of Horticulture, DK-5792 Aarslev, Denmark*

**Abstract:** In a three-year trial, the effect of plant spacing on yield and incidence of grey mould (*Botrytis cinerea* Pers.) was studied in a perennial matted row system and two cultivars of strawberry, ‘Elsanta’ and ‘Korona’. Three in-row plant distances were used, 25, 37 and 50 cm respectively, and all additional runners were removed each year. Lowering the in-row plant spacing from 50 to 25 cm generally increased total and marketable yield per hectare, whereas the berry size was unaffected, except from the third year during which berry size increased in ‘Elsanta’ with increased in-row plant distance. The level of *Botrytis* infection was very low the first and the third year and without any significant differences related to plant spacing. The second year, however, *Botrytis* infection levels generally were high and with significant differences between cultivars and plant distances. In general, ‘Korona’ was more heavily infected than ‘Elsanta’, and for both cultivars the level of infection increased with plant density. There were significant climatic differences between the three years. It is therefore concluded that climatic differences among years may be one of several factors of importance for Botytis infection. Also, it is concluded that, although increasing in-row plant spacing from 25 to 50 cm may cause a reduction in *Botrytis* infection level, it is of minor importance and marketable yield is still higher at the lowest plant spacing.

**Key words:** Strawberry, *Botrytis cinerea* Pers., plant spacing, yield, berry size

**Introduction**

During the past few years, the Danish environmental authorities have critically reviewed all pesticides used in Danish agriculture and horticulture, and a considerable number of pesticides have been banned. Due to this situation, the environmental authorities sponsored a research project in strawberries with the aim of investigating the effect of cultural methods in the control of grey mould (*Botrytis cinerea* Pers.). One of the alternatives included were plant spacing, which is known to affect the occurrence of *Botrytis* to various degrees. Recent research results are reviewed in a previous publication (Daugaard, 1999b).

**Materials and methods**

A+ frigo plants of two cultivars (‘Elsanta’ and ‘Korona’) were planted in matted row system in May 1997. Each plot consisted of 6 rows with 15 plants in each row. The plant spacing in the row was 0.25, 0.37 and 0.50 m, respectively. The row spacing used was 0.9 m, and in all parts of the experiment 4 replications were included. All flowers were removed by hand six weeks after planting. During the season, the plots were fertilised during flowering according to soil and leaf analyses and irrigated in dry periods. Weeds were controlled mechanically including the use of rotary cultivator 2-3 times per year and supplementary hand hoeing in the rows. All runners between rows were removed mechanically after harvest. Runners in the row were removed by hand leaving the original plants as separate plants. The plants were
protected during the winter period by covering with agryl (synthetic mulch supplied by Garta Ltd.). Pests and diseases were controlled according to normal practice, but in order to assess the infection level of *Botrytis* correctly, no fungicides were applied during the trial. The experiment was extended to three cropping years in order to follow the development of *Botrytis* for as long as possible. Each of the three years 6 tonnes of cut wheat straw per hectare was placed between rows after flowering, and after harvest it was cultivated into the soil. Yield and berry size were recorded in all plots, but only for 12 plants situated in the middle of the 2 central rows of each plot. The rest of the plants were considered guard plants. Berries were picked twice a week from all plants, including the guard plants. The weight of marketable berries, *Botrytis*-infected berries and other not marketable berries was recorded separately. Berries less than 22 mm or misshapen were considered not marketable.

All data were subject to statistical analysis using the General Model of SAS (SAS Institute, Inc., 1989-95, Cary, NC). The least significant differences between means were determined at $P \leq 0.05$ using Duncan’s test.

### Results

#### Climate

The Climate in Denmark is mild-temperate and with considerable annual variation. This was also the case during the trial as illustrated in Table 1. Especially during flowering (May) and again during harvest (June-July), differences in weather conditions may result in different levels of *Botrytis* among years. During the first cropping year January-April was relatively mild and wet, whereas May-June was normal and July-August was colder than normal.

Table 1. Monthly climatic records for Aarslev in 1998, 1999 and 2000 compared to a 30-year average.

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean temperature, °C</th>
<th>Precipitation, mm</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>2.7</td>
<td>2.4</td>
<td>3.0</td>
<td>-0.2</td>
<td>82</td>
<td>99</td>
<td>48</td>
<td>57</td>
</tr>
<tr>
<td>February</td>
<td>5.0</td>
<td>0.6</td>
<td>3.5</td>
<td>-0.4</td>
<td>33</td>
<td>96</td>
<td>63</td>
<td>38</td>
</tr>
<tr>
<td>March</td>
<td>3.9</td>
<td>4.0</td>
<td>3.9</td>
<td>1.7</td>
<td>54</td>
<td>73</td>
<td>57</td>
<td>46</td>
</tr>
<tr>
<td>April</td>
<td>6.9</td>
<td>8.1</td>
<td>8.7</td>
<td>6.4</td>
<td>86</td>
<td>31</td>
<td>47</td>
<td>41</td>
</tr>
<tr>
<td>May</td>
<td>11.8</td>
<td>11.3</td>
<td>12.8</td>
<td>11.3</td>
<td>38</td>
<td>43</td>
<td>31</td>
<td>48</td>
</tr>
<tr>
<td>June</td>
<td>14.5</td>
<td>13.5</td>
<td>13.9</td>
<td>14.7</td>
<td>75</td>
<td>102</td>
<td>44</td>
<td>55</td>
</tr>
<tr>
<td>July</td>
<td>14.6</td>
<td>17.4</td>
<td>14.8</td>
<td>16.6</td>
<td>76</td>
<td>47</td>
<td>30</td>
<td>66</td>
</tr>
<tr>
<td>August</td>
<td>14.9</td>
<td>16.7</td>
<td>15.3</td>
<td>16.3</td>
<td>44</td>
<td>67</td>
<td>45</td>
<td>67</td>
</tr>
<tr>
<td>Average Jan.-Aug.</td>
<td>9.3</td>
<td>9.3</td>
<td>9.5</td>
<td>8.3</td>
<td>61</td>
<td>70</td>
<td>46</td>
<td>52</td>
</tr>
</tbody>
</table>

During the second year, January-April was considerably milder than normal and rainfall nearly doubled. In June, the average temperature was below normal and with heavy rainfalls, whereas in July and August the weather conditions were warm and dry. Finally, the third year of trial was characterised by very mild weather from January through till May and, especially during flowering in April-May, very warm and dry. Contrary to this, the summer months (June-August) were chilly and with precipitation below normal.
Yield and berry size

In Table 2 results concerning the effect of plant spacing on yield are outlined for the three years of trial. Results are shown for both cultivars combined as well as separately. When data for both cultivars combined are considered, the highest total yield was obtained at the lowest in-row plant distance (25 cm) in all cropping years. However, differences were not significant in all cases. Based on a 3-year average and both cultivars, the total yield at a 25-cm plant distance was 28.2 t/ha declining to 21.1 t/ha at 50 cm, a 34% difference. The two cultivars responded very differently to variable plant spacing as well as plant age. The total yield of ‘Korona’ was at the highest level the first cropping year and with significant differences between plant distances. The second and third year the total yield declined, and with little or no differences between plant distances. As far as ‘Elsanta’ was concerned, the highest total yield and the most pronounced effects of plant spacing were obtained during the second cropping year, whereas the yield during the first year was low and with no significant effects of plant spacing. When marketable yield is considered, the results were essentially similar, but at a lower level than for total yield.

Table 2. Total yield, marketable yield and berry size in 1998, 1999 and 2000.

<table>
<thead>
<tr>
<th>Variety/Plant distance</th>
<th>Total yield tons per ha</th>
<th>Marketable yield tons per ha</th>
<th>Berry size g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both cultivars</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 cm</td>
<td>27.3a</td>
<td>35.3a</td>
<td>22.1a</td>
</tr>
<tr>
<td>37 cm</td>
<td>23.3b</td>
<td>32.0a</td>
<td>23.0a</td>
</tr>
<tr>
<td>50 cm</td>
<td>20.6b</td>
<td>25.3b</td>
<td>17.3b</td>
</tr>
<tr>
<td>‘Korona’</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 cm</td>
<td>37.5a</td>
<td>32.6a</td>
<td>19.6a</td>
</tr>
<tr>
<td>37 cm</td>
<td>32.8b</td>
<td>33.1a</td>
<td>18.8a</td>
</tr>
<tr>
<td>50 cm</td>
<td>28.2c</td>
<td>27.9b</td>
<td>14.5a</td>
</tr>
<tr>
<td>‘Elsanta’</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 cm</td>
<td>17.1a</td>
<td>38.0a</td>
<td>25.6a</td>
</tr>
<tr>
<td>37 cm</td>
<td>13.8a</td>
<td>30.8b</td>
<td>27.3a</td>
</tr>
<tr>
<td>50 cm</td>
<td>13.1a</td>
<td>22.6c</td>
<td>19.2b</td>
</tr>
</tbody>
</table>

In Table 2 the effect of plant spacing on berry size is outlined. Significant effects are limited to the third cropping year in Elsanta, showing a decline in berry size with lower plant spacing. A similar decline is seen in Korona, but the results are not significant.

Botrytis infection

The level of Botrytis infection during the trial is shown in Table 3. When data for both cultivars combined are considered, there is a marked difference among years. During the first cropping year, the level of infection was very low (<7 %) and with no significant effect of plant spacing, whereas during the second year the yield loss caused by Botrytis was considerable (14-37%) and with significant differences between plant distances. On average there was a yield loss increase of 3.9 t per ha from 25 to 50-cm plant distance. The third year Botrytis infection level was again low (<11%). The results clearly demonstrate differences in susceptibility among varieties, ‘Korona’ being a more susceptible cultivar than ‘Elsanta’.

<table>
<thead>
<tr>
<th>Variety/Treatment</th>
<th><em>Botrytis</em>, t/ha 1998</th>
<th><em>Botrytis</em>, t/ha 1999</th>
<th><em>Botrytis</em>, t/ha 2000</th>
<th><em>Botrytis</em>, % of total yield 1998</th>
<th><em>Botrytis</em>, % of total yield 1999</th>
<th><em>Botrytis</em>, % of total yield 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both cultivars</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 cm</td>
<td>1.3a</td>
<td>9.4a</td>
<td>1.3ab</td>
<td>4.8</td>
<td>26.7</td>
<td>7.9</td>
</tr>
<tr>
<td>37 cm</td>
<td>1.2a</td>
<td>8.4a</td>
<td>1.9a</td>
<td>5.2</td>
<td>26.3</td>
<td>9.4</td>
</tr>
<tr>
<td>50 cm</td>
<td>1.3a</td>
<td>5.5b</td>
<td>1.0b</td>
<td>6.3</td>
<td>21.7</td>
<td>8.3</td>
</tr>
<tr>
<td>‘Korona’</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 cm</td>
<td>1.7a</td>
<td>12.0a</td>
<td>1.1a</td>
<td>4.5</td>
<td>36.8</td>
<td>8.0</td>
</tr>
<tr>
<td>37 cm</td>
<td>1.9a</td>
<td>11.5a</td>
<td>1.5a</td>
<td>5.8</td>
<td>34.7</td>
<td>8.4</td>
</tr>
<tr>
<td>50 cm</td>
<td>1.6a</td>
<td>7.9b</td>
<td>1.1a</td>
<td>5.7</td>
<td>28.3</td>
<td>10.0</td>
</tr>
<tr>
<td>‘Elsanta’</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 cm</td>
<td>0.8a</td>
<td>6.7a</td>
<td>1.7b</td>
<td>4.7</td>
<td>17.6</td>
<td>7.7</td>
</tr>
<tr>
<td>37 cm</td>
<td>0.6a</td>
<td>5.2a</td>
<td>2.2a</td>
<td>4.3</td>
<td>16.9</td>
<td>10.5</td>
</tr>
<tr>
<td>50 cm</td>
<td>1.0a</td>
<td>3.1b</td>
<td>1.0c</td>
<td>7.6</td>
<td>13.7</td>
<td>7.1</td>
</tr>
</tbody>
</table>

Especially the second year of trial, with high incidence of *Botrytis*, the percentage in ‘Korona’ was twice as high as in ‘Elsanta’.

**Discussion**

In this study it was found that the highest total yield as well as marketable yield was obtained at the lowest in-row plant distance included (25 cm). This corresponds well to a number of research reports, showing that a lower in-row plant distance may result in a lower yield per plant, but a higher yield per hectare (Sønsteby et al., 1996; Meås and Solberg 1996; Legard et al., 2000). Differences regarding yield and berry size among cultivars, similar to differences found in this study, also are well known. Studies including effects of plant spacing on *Botrytis* incidence are, however, sparse. Since relative humidity is an important factor in the biology of *B. cinerea* an influence of good aeration around strawberry plants on the disease incidence is expected (Daugaard, 1999a; 1999b). Observations have indeed indicated that factors promoting air circulation within the strawberry canopy are a crucial part of a *B. cinerea* management programme. In IPM programmes of the northeastern United States, site selection to promote air drainage, row widths less than 60-70 cm and excellent weed control are encouraged (Cooley et al., 1996). Such recommendations are based on a number of research results showing good correlation between *B. cinerea* incidence and plant density (Dijkstra and van Oosten, 1985; Sutton et al., 1988; Sønsteby et al., 1996), although according to some reports the effect is little or negligible (Wilcox et al., 1994; Meås and Solberg, 1996). Plant density in this connection is defined as distance between plants as well as row distance. Most of the experiments on this topic, however, are performed according to standard disease control practices using chemical fungicides, which may reduce the effect of plant density on *B. cinerea* incidence. In organic farming, a single row system generally is recommended to secure good aeration around the strawberry plants (Martinsson, 1988; Daugaard, 1999a; Daugaard, 1999b; Opstad et al., 1998 Schmid, 1996). According to some experiments, double or triple row systems cause increased incidence of *B. cinerea* (Dijkstra and van Oosten, 1985; Strik et al., 1997), which makes them unsuitable in organic as well as IPM systems.

In this study, no fungicides were applied in order to assess the infection levels of *Botrytis* independent of chemical plant protection. The results indicate that lowering the in-row plant
distance may result in an increased Botrytis incidence. However, in the first cropping year the plants were not fully-grown and this may be one factor explaining the low degree of infection. Another factor to be considered is the climate, especially during flowering, where Botrytis infection normally occurs. The Botrytis incidence was relatively low during the third cropping year, which was characterised by dry and warm weather during flowering. Climatic factors, therefore, may play a more important role in the control of Botrytis, than differences in plant density. Apparently increasing the plant distance may result in a lower amount of Botrytis-infested berries but at the same time the yield per hectare is lowered even more.

Conclusions

In strawberries, Botrytis is considered the most important fungal disease and no resistance genes are known to exist. However, there is a marked difference in susceptibility among cultivars and furthermore different cultural methods may be of importance in the control of Botrytis. In this study, the effect of plant spacing was studied and it is concluded that, although increasing in-row plant spacing from 25 to 50 cm may cause a reduction in Botrytis infection level, it is of minor importance and marketable yield is still higher at the lowest plant spacing. Furthermore, climatic differences among years may be a more important factor affecting Botrytis infection than increasing the in-row plant spacing.

References

Control of Botrytis Grey Mould on Raspberry and Red Currant

Erich Jörg¹, Uwe Harzer², Werner Ollig²  
¹ Landesanstalt für Pflanzenbau und Pflanzenschutz, Essenheimerstr. 11, 55128 Mainz, Germany  
² Staatliche Lehr- und Forschungsanstalt für Landwirtschaft, Weinbau und Gartenbau, Breitenweg 71, D-67435 Neustadt/Wstr., Germany

Abstract: *Botrytis cinerea* is the most important and widespread fungal disease in German raspberry production. Resistant cultivars are not available. Three to five treatments per season are necessary to control grey mould. To a lesser extent *Botrytis* grey mould occurs on fruits of red currant. Results are presented from fungicide trials at Rheinland-Pfalz (southwestern Germany). Teldor (Fenhexamid), Switch (Cyprodinil+Fludioxonil) and Scala (Pyrimethanil) gave good *Botrytis* control with higher degrees of efficacy than the standard product Euparen (Dichlofluanid). Switch was the most effective product. The fungicide treatments increased yields considerably. In the past *Botrytis* control was solely based on Euparen. With the registration of the new products a fungicide resistance management as required by IOBC-Guidelines for Integrated Production of Soft Fruit seems to be possible.

Key words: Raspberry, Red Currant, *Botrytis cinerea*, fungicides, resistance management, cultivars, integrated control.

Introduction

Raspberry production area in Germany is about 500 ha with few specialised growers. They are usually self-marketers who want to have a wide range of fruit. Yields range from 9 to 12 t/ha and prices vary between 5.2 and 12.0 DM/kg. Higher prices are obtained for early market supply. Thus raspberry is a highly profitable crop. Many fungal diseases infect the crop, but the most widespread and serious pathogen is *Botrytis cinerea* (Gordon and Woodford, 2000). Botrytis grey mould causes the highest losses in raspberry production. In addition the fungus also is part of the “cane diseases complex”. Raspberry rust is of minor importance.

In many areas of Germany 3-6 fungicide treatments are applied but in intensive cropping systems the maximum number of applications varies from 4 to 10. For more than a decade Dichlofluanid was the only active ingredient registered for *Botrytis* control in raspberries in Germany but since 2000 Fenhexamid (Teldor) has also been registered. This unsatisfactory registration situation where the same active ingredient is used several times in a season may lead to fungicide resistance. Additionally, Nowacka (2000) showed that residues of botryticides were found on strawberry, raspberry and currant fruits after intensive use. These problems require an integrated approach to control *B. cinerea*, including the search for new fungicides to permit an efficient anti-resistance management.

Integrated approach for *Botrytis* control on raspberry

Table 1 gives an overview on non-chemical measures that may be employed to contribute to *Botrytis* grey mould control in raspberry production.
**Cultivar choice**

Cultivars combining good agronomic and fruiting quality with a low susceptibility to pests or diseases are rare. This also holds for raspberry cultivars (Table 2) and in several cases resistance to cane *Botrytis* was correlated with higher susceptibility to powdery mildew and yellow rust (Williamson and Jennings, 1992).

The cultivars grown in Germany may be grouped into three ripening classes. In the early group only “Elida” is of importance, a cultivar of medium quality but also medium susceptibility to *B. cinerea*. However this early market segment is very small. On most of the growing area the mid-season ripening cultivars “Malling Exploit”, “Meeker”, “Schönenmann” and “Tulameen” are the most popular cultivars. “Meeker” shows a low *Botrytis* susceptibility and has increased during the last three years. “Schönenmann” remains the most frequently grown cultivar, however, growing area of “Malling Exploit” and “Tulameen” is also increasing. In the late ripening group “Autumn Bliss” is the dominating cultivar. “Autumn Bliss” is very susceptible to *B. cinerea* and requires three to four treatments in order to achieve acceptable yields. Possibly “Himbo Top” will replace this susceptible cultivar in the long run.

Table 1. Integrated approach for *Botrytis* control on raspberry efficiency and acceptance of non chemical measures

<table>
<thead>
<tr>
<th>Measure to be taken</th>
<th>Efficiency</th>
<th>Acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivar</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Growing system</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Fertilisation</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Weed control</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td>Harvest</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Protected systems</td>
<td>+++</td>
<td>– / (+)</td>
</tr>
</tbody>
</table>

Table 2. Properties of raspberry cultivars

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Growing area</th>
<th>Fruit quality colour, size, taste</th>
<th>Botrytis susceptibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elida</td>
<td>+</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Mall. Exploit</td>
<td>++</td>
<td>++(+)</td>
<td>+++</td>
</tr>
<tr>
<td>Meeker</td>
<td>+++</td>
<td>+/+++</td>
<td>+</td>
</tr>
<tr>
<td>Schönenmann</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Tulameen</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Glen Ample</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Autumn Bliss</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Himbo Star</td>
<td>+</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td>Himbo Top</td>
<td>–</td>
<td>+++</td>
<td>+</td>
</tr>
</tbody>
</table>
Resistance to *B. cinerea* may be modified by weather conditions. In rainy periods at the end of summer almost all cultivars show high infestation levels. Thus the efficiency of “resistance” to *B. cinerea* should not be overestimated.

**Growing system**

Plantations should not be too dense. Good wind penetration results in reduced moisture within the crop and thus unfavourable conditions for *B. cinerea*. The aim should be 10-15 canes per meter row length. In general German growers respect this recommendation. However the influence of density of plantations on grey mould infestation is of minor importance according to Cruz (1993).

**Fertilisation**

The influence of Nitrogen supply on the occurrence of *B. cinerea* is significant (Cruz, 1993). During the last decade the amount of Nitrogen fertiliser input has been reduced considerably in raspberry crops. A fertilisation scheme has been developed that limits the maximum fertilisation rate to 100 kg/ha in raspberries. The average application rate ranges from 60 to 75 kg/ha. As Nitrogen should be supplied evenly application rates higher than 50 kg/ha must be split. Half of the Nitrogen should be applied via organic manure and the mineralisation of mulching material must be taken into consideration. This fertilisation scheme is widely accepted by the growers and contributes to the reduction of *Botrytis* infestation in the crops (Neuweiler and Bak, 2001).

**Weed control**

Mulching with bark, manure or black plastic foliage gives effective weed control and also reduces the probability of *B. cinerea* infections to a certain extent. Recently mulching is a standard measure in German raspberry production contributing to an Integrated Control of *Botrytis* grey mould.

**Harvest**

The removal of fruiting canes immediately after harvest is a phytosanitary measure which can reduce the inoculum of *Botrytis* (also other cane diseases). The risk for cane diseases is less in the following year. The efficiency in reducing *Botrytis* grey mould however is limited and in addition with respect to keeping predatory mites in the crop fruiting canes should not be removed too early.

**Protected systems**

Mobile tunnels and roof constructions above the crop prevent precipitation and are very effective in reducing the risk of *Botrytis* grey mould. Often a *Botrytis* control is not necessary at all (Faby, 2001). But because the costs for such systems are very high and the financial risk is enormous they only should be used on a limited scale (for highly profitable early raspberry varieties). In addition the infestation with red spider mite and other pests increases demanding extra acaricide and insecticide treatments or biological control measures (Faby, 2001). Acceptance of protected systems in practice is low.

**Fungicide use**

Even if all non-chemical measures are used fungicide treatments are necessary to control *B. cinerea*. From blossoming on when the contents of soluble sugars increase within the inflorescences *B. cinerea* infections occur (Campos et al., 1995).

**Trials**

In 1998, 1999 and 2000 three trials (block design with four replications) were laid out to test new active ingredients for their efficacy to control *Botrytis* grey mould. Plots consisted of 25 (raspberry) resp. 10 (red currant) plants each. Details on the trials are given in Tables 3 and 4.
From blossoming on three to four treatments were applied with the same product. In 1999 in raspberry a spraying schedule consisting of two Switch applications followed by two fenhexamid sprays was included into the trial.

Table 3. Trials on Botrytis cinerea control in raspberry and red currant - cultivars, fungicides, application dates

<table>
<thead>
<tr>
<th>Year</th>
<th>Cultivar</th>
<th>Plant.</th>
<th>H₂O l/ha</th>
<th>Fungicides (treatments)</th>
<th>Application dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>Meeker (Rasp.)</td>
<td>1997</td>
<td>600</td>
<td>Euparen WG</td>
<td>1) 20.5./60*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Teldor SC</td>
<td>2) 27.5./65</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Switch</td>
<td>3) 9.6./71</td>
</tr>
<tr>
<td>1998</td>
<td>Schönemann (Rasp.)</td>
<td>1997</td>
<td>1000</td>
<td>Euparen M WG (1,2,3)</td>
<td>1) 21.5./61-63</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Scala (1,2,3)</td>
<td>2) 29.5./65</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Switch (1,2,3)</td>
<td>3) 9.6./71-72</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Teldor WG (1,2,3,4)</td>
<td>4) 18.6./81</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Switch (1,2)+Teldor WG(3,4)</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>Rovada (Red Curr.)</td>
<td>1996</td>
<td>500</td>
<td>Euparen WG (1,2,3,4)</td>
<td>1) 25.4./65</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Teldor SC (1,2,3,4)</td>
<td>2) 5.5./69</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Switch (1,2,3)</td>
<td>3) 11.5./75</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>18.5./79</td>
</tr>
</tbody>
</table>

* BBCH-scheme

Table 4. Control of Botrytis cinerea on raspberry and red currant - fungicides, active ingredients, dosage rates

<table>
<thead>
<tr>
<th>Product</th>
<th>Dosage rate</th>
<th>Active ingredient</th>
<th>Content</th>
<th>a.i. group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euparen WG</td>
<td>0.2 %</td>
<td>Dichlofluanid</td>
<td>515 g/kg</td>
<td>„Sulfamids“</td>
</tr>
<tr>
<td>Euparen M WG</td>
<td>0.15 %</td>
<td>Tolylfluanid</td>
<td>500 g/kg</td>
<td>„Sulfamids“</td>
</tr>
<tr>
<td>Teldor SC</td>
<td>0.2 %</td>
<td>Fenhexamid</td>
<td>500 g/kg</td>
<td>Hydroxyanilid</td>
</tr>
<tr>
<td>Teldor WG</td>
<td>0.1 %</td>
<td>Fenhexamid</td>
<td>500 g/kg</td>
<td>Hydroxyanilid</td>
</tr>
<tr>
<td>Scala</td>
<td>0.15 %</td>
<td>Pyrimethanil</td>
<td>400 g/l</td>
<td>Anilinopyrimidin</td>
</tr>
<tr>
<td>Switch</td>
<td>0.05 %</td>
<td>Cyprodinil</td>
<td>375 g/kg</td>
<td>Anilinopyrimidin</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fludioxinil</td>
<td>250 g/kg</td>
<td>Phenylpyrrol</td>
</tr>
</tbody>
</table>

The fungicides were applied with 500 to 1000 l/ha water. Assessments on the fruits were done after 4 resp. 8 days of storage at 20°C for raspberry and at harvest and after 7 days of storage at 20°C for red currant. The trials were laid out close to Neustadt/Wstr. in the Palatinate region within the “minor uses” programme of the German governmental crop protection service of Rheinland-Pfalz.

Results

a) Raspberry

Results of the trials for raspberry are shown in Figures 1 and 2. In 1998 36 % of the fruits in the untreated plots were diseased. The standard product tolylfluanid did not reduce the disease at all. All other treatments showed efficacies ranging from 52 % to 78 %. Three cyprod.
Pyrimeth. applications gave best control. A schedule with two cyprod. + fludiox. applications followed by two fenhexamid sprays did not improve the degree of efficacy.

1999 also was a year with strong *B. cinerea* epidemic pressure and half of the fruits in the untreated plots were infected with the fungus (Fig. 2). Efficacies in general were lower than in 1998. Again cyprod. + fludiox. gave best control (33 % efficacy) followed by fenhexamid (25 %) and dichlofluanid (17 %). These results are in accordance with results of other German researchers (Fig. 3). A summary of all *Botrytis* trials with fungicides confirm the unsatisfactory control efficacy of dichlofluanid resp. tolylfluanid. Mean efficacy was 34 % in 14 trials. Again cyprod. + fludiox. gave best control (61 – 68 % depending on the dosage rate applied). Satisfying results were obtained with fenhexamid and pyrimethanil (65 % resp. 55 %). In seven of the trials with dichlo-/tolylfluanid degrees of efficacy were lower than 25 % and maximum disease control found was 72 %. For the other fungicides no efficacy lower than 30 % was observed and the maximum degrees of efficacy were 88 %, 89 % and 96 % for pyrimethanil, cyprod. + fludiox. and fenhexamid.

On strawberry Bielenin, Meszka (2000) and Meszka et al. (2000) also reported on unsatisfying degrees of efficacy for dichlofluanid in *B. cinerea* control ranging from 6 % to 74 %. In comparison of dichlofluanid and fenhexamid the latter fungicide always gave better control. Dichlofluanid showed higher degrees of efficacy than tolylfluanid. In some of the trials carried out between 1997 and 2000 we also could confirm this observation.

Figure 1. Control of *Botrytis* Grey Mould on raspberry 1998 – fungicide efficacy

Figure 2. Control of *Botrytis* Grey Mould on raspberry 1999 – fungicide efficacy
Untreated Euparen WG Teldor SC Switch

50.7  42.3  38.3  33.9  33

Figure 3. Summary of German fungicide trials for *Botrytis* Grey Mould control from 1997 – 2000 (mean efficacy %, number of trials in brackets)

Untreated Euparen WG Teldor SC Switch

51.7  47.4  8.3  5.9  10.4  88.6  79.9

Figure 4. Control of *Botrytis* Grey Mould on red currant (diseased racemes and efficacy after storage, 14th of July 2000)

b) Red Currant

Results on *Botrytis* control on red currant are reported from one trial. In 2000 about 5% of the racemes at harvest were infected by *B. cinerea*. Four applications of dichlofluanid and fenhexamid resulted in an efficacy of 56% and 67%. Best control was achieved by three cyprod. + fludiox. applications (86%). After one week of storage the situation had changed (Fig. 4) completely with more than 50% of the racemes from the untreated plots being diseased.

Dichlofluanid treatments showed only 8% efficacy whereas cyprod. + fludiox. reduced the disease by 80%. The best control was by fenhexamid (89%). Due to a shorter safe to harvest – interval the fourth fenhexamid treatment was applied one week closer to harvest than the third treatment with the other products which may be the reason for the very good efficacy of the product.

Fungicide Resistance

Fungicide resistance of *B. cinerea* from many crops to several groups of active ingredients is widespread (e.g. Meszka and Bielenin, 1999; Johnson et al., 1994). Especially benzimidazole and dicarboximid resistant strains occur frequently. According to Yourman et al. (2001) this
resistance is stable. Kim et al. (1996) reported on dichlofluanid resistant \textit{B. cinerea} strains. Since 1994 strains highly resistant to antinopyrimidins (pyrimethanil) occur in French vineyards and since 1999 in Italian ones (Chapelard et al., 1999; Gullino et al., 2000). Up to now no phenylpyrrol resistance of \textit{B. cinerea} has been observed (Gullino et al., 2000). This also holds for hydroxanilids (fenhexamid) under outdoor conditions (Suty et al., 1999). But under laboratory conditions some isolates showed a reduced sensitivity to fenhexamid (Suty et al., 1999).

Multiple resistance of \textit{B. cinerea} strains also seems to be widespread. (Gullino et al., 2000; Johnson et al., 1994). On the other hand some groups of active ingredients (phenyl-pyrimidinamines, hydroxyanilids) exhibited no cross-resistance to others (Kalamarakis et al., 2000; Suty at al., 1999).

The share of resistant strains rapidly increases depending on the fungicide use. Johnson et al. (1994) observed an increase of resistant \textit{B. cinerea} strains by 21% in strawberry and 6% in raspberry after a single application of vinclozoline. Meszka and Bielenin (1999) also found that after three years of benzimidazole use most of the \textit{B. cinerea} strains were resistant.

\textbf{Conclusion}

According to Brent and Hollomon (1998) the basic disease risk for fungicide resistance of \textit{B. cinerea} is high. The basic fungicide risk for resistance for some groups of botryticides is either high (e.g benzimidazoles) or at least medium (anilinopyrimidins, phenylpyroles). So there is considerable risk for the development of fungicide resistance of \textit{B. cinerea} to the most commonly used botryticides. In several cases this has been proven and the unsatisfying results of some fungicides in our trials are at least partly due to fungicide resistance.

In order to prolong the live span of the few fungicides available for \textit{Botrytis} control an effective anti-resistance management as required by the IOBC – Technical Guidelines III for Integrated Production of Soft Fruit is absolutely necessary. Despite their limited efficacy all non-chemical measures have to be taken to reduce \textit{Botrytis} pressure in the crops. In general German farmers use these measures to a high extent. Nevertheless fungicide applications are necessary to control \textit{B. cinerea} efficiently. The choice of products should not be done with respect to efficacy against \textit{B. cinerea} only but should also take into consideration the efficacy on other fungal diseases occurring in the crops to restrict the fungicide load of the crops to the minimum. For the new products information on this is still incomplete. Within the spraying schedule the groups of active ingredients should be rotated according to the mode of action to prevent or at least delay fungicide resistance as long as possible. Winter et al. (1998), the FRAC – recommendations (Brent and Hollomon, 1998) and Olszak et al. (2000) give good guidance for an effective anti-resistance management. A decision support system for \textit{Botrytis} control similar to the BOTEM system (Berrie et al., 2000) would also contribute to the restriction of fungicide application to the minimum. Berrie at al. (2000) could reduce the number of fungicide applications in strawberry by 50 % whilst keeping could fungal control.

\textbf{References}


Abstract

Prospects for integrated control of raspberry root rot

James M. Duncan
Scottish Crop Research Institute, Invergowrie, Dundee DD2 5DA, Scotland, UK

Root rot is currently the most serious disease facing raspberry producers in Europe. Diseased plants either yield very little or are killed and small areas affected by the disease can rapidly develop into very large patches, thereby rendering production uneconomic. The principal cause of root rot is Phytophthora fragariae variety rubi but other Phytophthora species are sometimes involved. At present the disease is controlled largely by fungicides but even at relatively high levels, these can be inconsistent in their effect. Other possible control elements include growing plants on ridges and under plastic mulches but the most important element that has been identified is host resistance. Some existing cultivars already have valuable levels of resistance but the majority do not. Combining resistance with the other measures above and with reduced levels of fungicides can give satisfactory control but obtaining the necessary levels of resistance in suitable commercial cultivars will take much time and effort.
A review of research on epidemiology and control of blackspot of strawberry (*Colletotrichum acutatum*) with special reference to weeds as alternative hosts

A. M. Berrie¹, C. M. Burgess²

¹ Horticulture Research International - East Malling, West Malling, Kent, ME19 6BJ, UK
² Horticulture Research International - Efford, Lymington, Hants, SO41 0LZ, UK

Abstract: Blackspot (*Colletotrichum acutatum*) is one of the most important causes of fruit rot in strawberry and is present in most strawberry growing areas of the world. The disease can occur on all parts of the plant, including the crown and roots, but it is primarily a disease of ripe fruit. *Colletotrichum acutatum* has a wide host range, including many fruit and vegetable crops, ornamentals and weeds. Blackspot is favoured by warm temperatures (optimum 25-30°C), high humidity and rain and, under these conditions, lesions become covered in salmon-pink slimy conidial masses that are easily spread by rain splash, pickers and contaminated equipment. The disease is spread into new areas mainly on symptomless infected planting material. Control of the disease is dependent on an integrated approach combining cultural methods, use of fungicides and resistant varieties, where available. Studies on weeds as alternate hosts for *C. acutatum* in the UK showed that, in glasshouse inoculation tests, all 35 species of weeds commonly found in strawberry fields could become infected with the *C. acutatum*, but symptoms were present on only seven of the weeds tested. In a field trial weeds, inoculated with *C. acutatum* and treated or untreated with paraquat, were introduced into plots of strawberries cv Elsanta either in the autumn or following spring. Blackspot was recorded on fruit or petioles of strawberries in all plots where inoculated weeds were introduced. None was detected in control plots, containing uninoculated weeds. The highest incidence of blackspot on fruit (30%) and petioles (50%) was recorded in plots where inoculated weeds treated with paraquat had been planted.

Key words: Strawberry, anthracnose, paraquat, blackspot, fungicide.

Introduction

Blackspot, caused by the fungus *Colletotrichum acutatum*, was first recorded in the UK in 1983 on the variety Brighton, introduced from California. Action taken by MAFF to contain the disease was initially successful with only sporadic further outbreaks. However, in the last five years the incidence of blackspot in outdoor fruiting crops has increased so that it is now becoming an important disease of strawberry in the UK, with about 10% of crops affected (Lovelidge, 2001). This is mainly because of its ability to spread rapidly through crops, particularly near harvest, and the lack of easily implemented effective control measures. Losses can occasionally be significant in June-bearer crops, but most losses in the UK are in everbearer strawberry crops, where as much as 80% of the fruit can be infected resulting in almost total crop loss. The purpose of this paper is to briefly review current knowledge on the epidemiology and control of *C. acutatum* and to report the results of recent work on the possible role of weeds in the epidemiology of the disease in the UK.

Review of epidemiology and control

*Colletotrichum acutatum* attacks all above ground parts of the strawberry plant, but it is primarily a disease of ripe fruit, both pre and post harvest. Black lesions are seen on ripe fruit,
green fruit, petioles, stolons, flower buds and flower stalks, and these become covered with salmon pink / orange slimy spore masses when the weather is humid or wet. *C. acutatum* may also cause leaf spot, crown rot (Santos et al., 1999) and root rot (Freeman and Katan, 1997). The fungus can attack a wide range of crop plants and ornamentals. In the UK it has been recorded on anemone, lupin (Reed et al., 1996), Camellia and apple and elsewhere on a wide range of vegetable and fruit crops (Freeman and Shabi, 1996) and on weeds.

*Colletotrichum acutatum* is favoured by warm temperatures (optimum 25-30°C), high humidity and rain. The conidia are spread by rain splash and spore dispersal and subsequent infection of fruit can occur with <15 mins duration of rain. Optimum temperatures and 13 hours of wetness can result in more than 80% fruit infection (Wilson et al., 1990). *Colletotrichum acutatum* has also been shown to increase on the plant surface without showing symptoms (Leandro et al., 2001), which probably explains why blackspot can suddenly appear on strawberry fruits without other plant symptoms. The disease is also favoured by high nitrogen (Smith, 1987). *Colletotrichum acutatum* is generally introduced into new areas and crops on symptomless infected planting material. Localised spread is by water splash and research has shown that this spread is much greater in strawberry crops on plastic mulch or bare soil than on straw mulch (Yang et al., 1990). The sticky slimy conidia are also easily spread by pickers on hands and contaminated clothes. In studies the fungus has been shown to survive as dried slime on clothes for up to five weeks (Norman and Strandberg, 1997). *Colletotrichum acutatum* overwinters on infected strawberry plants or on weeds (Anon, 1989) and can survive between crops on infected crop debris, the length of survival time depending on conditions (Eastburn and Gubler, 1990).

Control of blackspot on strawberries requires an integrated approach in which cultural measures are as important as the use of fungicides. Most important is the use of healthy planting material to avoid introducing the disease into clean areas. Resistant varieties of strawberry, such as Sweet Charlie, are available in the USA and may be available in the future in the UK, but currently the commercially acceptable varieties are all susceptible to *C. acutatum*. Growing strawberry crops under protection will avoid problems with blackspot and reduce the risk of *Botrytis* rot, however the risk of powdery mildew is considerably increased.

Table 1. Efficacy of some fungicides in controlling strawberry blackspot (*Colletotrichum acutatum*), based on results from researchers in USA, Australia and Europe

<table>
<thead>
<tr>
<th>Fungicide</th>
<th>Efficacy</th>
<th>Fungicide</th>
<th>Efficacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>azoxystrobin</td>
<td>+++</td>
<td>iprodione</td>
<td>–</td>
</tr>
<tr>
<td>captan</td>
<td>+</td>
<td>kresoxim-methyl</td>
<td>++</td>
</tr>
<tr>
<td>carbendizim</td>
<td>–</td>
<td>myclobutanil</td>
<td>+</td>
</tr>
<tr>
<td>chlorothalonil</td>
<td>+</td>
<td>prochloraz</td>
<td>+++</td>
</tr>
<tr>
<td>cyprodinon +</td>
<td>+++</td>
<td>propiconazole</td>
<td>++</td>
</tr>
<tr>
<td>fludioxonil*</td>
<td>++</td>
<td>pyrimethanil</td>
<td>–</td>
</tr>
<tr>
<td>dichlofluanid</td>
<td>++</td>
<td>thiram</td>
<td>+</td>
</tr>
<tr>
<td>fenhexamid</td>
<td>–</td>
<td>tolylfluanid</td>
<td>++</td>
</tr>
<tr>
<td>fenpropimorph</td>
<td>++</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key: – little or no activity; + some activity; +++ good activity * active fungicide is fludioxonil

On outdoor crops the incidence of blackspot can be reduced by restricting nitrogen inputs to the crop, by use of straw mulch to reduce disease spread and by regular picking to avoid
the build up of ripe fruit. Removal of crop debris at the end of the season and good weed control, but avoiding the use of herbicides such as paraquat or glyphosate, which have been shown to encourage sporulation of *C. acutatum* (Cerkauskas, 1988), are also measures that will reduce the incidence of blackspot. The efficacy of some fungicides against *C. acutatum*, based on the results of research in USA, Australia and Europe are shown in Table 1.

**Weeds as alternate hosts**

*Colletotrichum acutatum* and the closely related species *C. fragariae* are reported to infect certain weed species in the USA (Anon, 1989; Howard et al., 1992) which may then act as sources of inoculum for subsequent strawberry crops. The purpose of this study was to investigate whether weeds in the UK were also susceptible to *C. acutatum* and also whether treatment of infected weeds with the herbicide paraquat, which is known to encourage sporulation of certain fungi (Cerkauskas, 1988), could encourage disease spread.

**Materials and methods**

**Tests on susceptibility of weeds to *C. acutatum***

Thirty-five weed species commonly found in strawberry crops in the UK were tested for susceptibility to *C. acutatum* in the glasshouse. Potted weeds were inoculated by spraying their foliage with a spore suspension consisting of a mixture of conidia (concentration 2.5 x 10^5 conidia/ml) from four isolates of *C. acutatum* all from UK strawberry crops. Inoculated weeds were then grown on in a glasshouse, maintained at 25°C and 90% relative humidity. The weeds were regularly inspected for symptoms and, after one month, were assessed and checked for symptoms and infection with *C. acutatum*.

**Glasshouse experiment**

In a replicated glasshouse experiment at HRI-East Malling, plants of *Geranium dissectum, Malva sylvestris, Chenopodium album* and *Prunella vulgaris* were inoculated with *C. acutatum* and placed among potted strawberry plants cv Calypso. In addition, similarly inoculated plants of the same weed species were treated with paraquat and also placed among potted strawberry plants in the glasshouse. Weeds which had not been inoculated or treated with paraquat were included as controls. The three treatments viz uninoculated weeds, inoculated weeds, inoculated + paraquat-sprayed weeds, were replicated six times in a randomised complete block design. Plots consisted of two rows each of seven potted strawberry plants separated by a row of five weed plants viz two *P. vulgaris* and one each of the other three weed species. Plants were grown at 25°C and 90% relative humidity and irrigated overhead to ensure disease development and spread of *C. acutatum*. The weeds and strawberry plants were checked regularly for symptoms.

**Field experiment**

Plants of *M. sylvestris, G. dissectum, C. album* and *Solanum nigrum*, uninoculated, inoculated with *C. acutatum* or inoculated with *C. acutatum* and sprayed with paraquat prior to planting, were planted in replicated plots of strawberry cv Elsanta in an isolated field at HRI-Efford on 19 December 1995. Similar weed plantings were made on 17 April 1996. The five treatments were replicated five times in a 5 x 5 latin square design. Each plot consisted of 20 strawberry plants arranged in a double row and grown on a raised, polythene mulched bed with trickle irrigation. Each plot was separated by 2.0m, mulched with straw, on all sides to minimise the risk of disease spread between plots. The plots were irrigated overhead (in addition to natural rain) on two occasions to encourage disease development within the plots. The strawberry plants and weeds were checked regularly for blackspot. Fruit was harvested and assessed for
blackspot on 19 and 27 June and on each occasion a sample of 25 sound fruit from each plot were incubated in a damp chamber in the laboratory at ambient temperature to check for post harvest rots. The incidence of blackspot lesions on petioles was recorded on 30 July.

Results and discussion

**Susceptibility of weeds to C. acutatum**

Leaf spots or stem lesions caused by *C. acutatum* were observed on seven weed species – *Ranunculus repens* (leaf spot), *Sinapis arvensis* (stem lesions), *Rumex obtusifolius* (leaf and stem spots), *Geranium dissectum* (leaf and stem spots), *Polygonum aviculare* (stem streaks), *Malva sylvestris* (leaf and stem spots) and *Plantago lanceolata* (leaf spots). In each case conidia typical of *C. acutatum* were found on the leaf or stem spots. No symptoms were observed on the other weed species. However, conidia of *C. acutatum* were detected on all symptomless weeds following incubation in damp chambers or treatment with paraquat prior to damp incubation. These results indicate that weeds in strawberry crops infected with *C. acutatum* could also become infected and possibly act as a source of inoculum for subsequent crops.

**Glasshouse experiment**

The paraquat treated weeds died rapidly but did not show any obvious sporulation of *C. acutatum*, although conidia could be detected in the tissue. Symptoms of blackspot were first noted on 12 February on strawberry fruits on plants in plots where inoculated paraquat-treated weeds had been introduced 12 days earlier. One week later blackspot was recorded on fruits in plots where inoculated non-paraquat treated weeds had been introduced. Once the disease had become established on the fruit, it spread rapidly to all strawberries in the trial, including the uninoculated control plots such that by 27 March 38.9, 58.6 and 42.6% of fruit from uninoculated, inoculated and inoculated + paraquat plots respectively, were infected with *C. acutatum*. The incidence of *C. acutatum* on petioles assessed on 27 March were similar to that on the fruit (35.9, 29.2 and 43.8% of petioles respectively). These results indicate that, under glasshouse conditions, *C. acutatum* can spread from weeds to strawberry plants and that treatment of weeds with paraquat encourages blackspot sporulation and spread.

**Field experiment**

In spring 1996, none of the paraquatated weeds and only a few plants of *M. sylvestris* and *G. dissectum*, planted the previous autumn, remained. Conidia of *C. acutatum*, however, could be detected on dead leaves when examined in the laboratory. No signs of blackspot were seen on the spring planted weeds. Blackspot, however, was present on fruit picked on 19 and 27 June from plots containing either autumn or spring planted inoculated weeds (Table 2). The highest incidence of blackspot lesions on fruit and petioles was recorded in plots where weeds had been treated with paraquat after inoculation with *C. acutatum* and planted in the spring. A low incidence of fruit and petioles with blackspot was detected in plots containing autumn planted weeds following laboratory tests with paraquat. No blackspot was detected in control plots, indicating the effectiveness of the inter plot straw mulch in minimising blackspot spread. The highest incidence of blackspot in post harvest tests (74.9% infected fruit) was recorded in fruit from plots with spring-planted weeds inoculated with *C. acutatum* and treated with paraquat (Table 2). The highest incidence of blackspot on the strawberries was in plots containing spring planted inoculated weeds, particularly those treated with paraquat. This shows that weeds infected with *C. acutatum* can act as a source of inoculum for strawberries and that treatment of such weeds with paraquat increases sporulation of *C. acutatum* resulting in a higher incidence of blackspot in the strawberries in those plots. Thus the risks associated with using paraquat for weed and runner control in strawberry crops infected with *C. acutatum*
must be taken into account when formulating strategies for disease management. The incidence of black spot in fruit from plots containing autumn planted weeds was considerably lower. This is most likely because the weeds were not planted until December when temperatures were low and not conducive to development of black spot on the weeds. Nevertheless black spot was detected in the strawberries in these plots, indicating that the fungus is able to overwinter on the plant debris remaining from the weeds.

Table 2. Incidence of black spot in strawberry fruits at harvest and in post-harvest tests and in petioles from plants from plots containing various weeds inoculated with *C. acutatum*

<table>
<thead>
<tr>
<th>Treatment</th>
<th>% strawberry fruit with blackspot</th>
<th>% infected strawberry petioles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Harvest 19 June</td>
<td>Harvest 27 June</td>
</tr>
<tr>
<td>Uninoculated weeds</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>Planted autumn 1995</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inoculated weeds</td>
<td>0.4</td>
<td>0.8</td>
</tr>
<tr>
<td>Inoculated weeds + paraquat</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>Planted spring 1996</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inoculated weeds</td>
<td>4.3</td>
<td>30.4</td>
</tr>
<tr>
<td>Inoculated weeds + paraquat</td>
<td>15.1</td>
<td>63.2</td>
</tr>
</tbody>
</table>

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References


Lovelidge, B. 2001: Blackspot emerging as key threat. The Grower, October 4, 8.


Wilson, L.L., Madden, L.V., & Ellis, M.A. 1990: Influence of temperature and wetness duration on infection of immature and mature strawberry fruit by *Colletotrichum acutatum*. Phytopathology 80: 111-116.

Yang, X., Wilson, L.L., Madden, L.V. & Ellis, M.A. 1990: Rain splash dispersal of *Colletotrichum acutatum* from infected strawberry fruit. Phytopathology 80: 590-595.
Important virus diseases of cane fruit crops and their control

A. Teifion Jones
Scottish Crop Research Institute, Invergowrie, Dundee DD2 5DA, Scotland, UK

Abstract: More than 30 virus or virus-like diseases are reported to occur in Ribes and Rubus crops worldwide and a few of these are of important economic significance in Europe. In Ribes, the major pathological problem is Blackcurrant reversion virus and its eriophyid gall mite vector, both of which cause serious damage. The only other virus disease of significance is Gooseberry vein banding. Effective control of reversion disease and of the blackcurrant gall mite vector seems very promising using plant genes for resistance to these organisms. However, the species structure, ecology and virus vector capabilities of the different eriophyid mites occurring on Ribes species needs to be studied in more detail to assess the likely stability of currently deployed mite resistance genes.

In Rubus, the most widespread virus and the most difficult to control is the pollen-borne Raspberry bushy dwarf virus (RBDV). Cultivars with resistance genes to common isolates of this virus are effective in preventing infection but the occurrence of resistance-breaking isolates (RB) pose serious problems for control. Because of the lack of suitable sources of resistance to these RB isolates in Rubus germplasm, engineered resistance using viral genes may offer the most appropriate means of control. Aphid-borne viruses, once controlled very effectively in the UK through the use of cultivars carrying genes for resistance to the main aphid vector, Amphorophora idaei, are now increasing in incidence due to the ability of aphid biotypes to overcome these resistance genes. The A. idaei-transmitted viruses causing Raspberry leaf spot mosaic disease are the most damaging in sensitive raspberry cultivars and their spread is not controlled effectively by the application of aphicides. No genes for resistance to these viruses are known but the inheritance of sensitivity to infection with some viruses is determined by single dominant genes, offering the possibility of breeding plants for tolerance to infection. Raspberry vein chlorosis virus, transmitted by the small raspberry aphid, Aphis idaei, is increasing in incidence in some cultivars posing problems for control, but strong resistance or immunity to the virus is present in some R. idaeus var. strigosus cultivars. Nematode-borne viruses are very damaging when they occur in crops, but they are usually very localised in occurrence. However, these viruses may become of more widespread significance following the withdrawal of commonly used soil sterilants in horticulture.

Key words: virus transmission, aphids, nematodes, eriophyid mites, pollen transmission, virus resistance, virus tolerance, virus vector resistance, Rubus, Ribes

Introduction

More than 30 virus or virus-like diseases are reported in Rubus and Ribes crops worldwide (Jones, 1992). However, only about a dozen of these are of economic significance on a world scale but some of these can damage crop production and/or quality severely. Viruses are transmitted between plants by plant-feeding vectors and the vector species associated with the transmission of the most important viruses in Rubus and Ribes crops in Europe are given in Table 1 together with the virus acronyms used throughout this paper.

Because viruses are obligate parasites that use the host plant biochemical machinery for their own replication and spread within plants, control of viruses in commerce is currently possible only by indirect means. These include the production of healthy planting material, the control of vectors to minimise spread within such initially healthy crops, and the use of
host plant resistance to virus infection, replication and spread within plants. This paper seeks to briefly summarise and evaluate these methods to control the important viruses and virus diseases in Table 1, to identify the current problems in using these different approaches to control, and to assess the future prospects of overcoming these difficulties.

Table 1. Important virus vector species on cane fruit crops in Europe and the viruses they transmit.

<table>
<thead>
<tr>
<th>Virus vector species</th>
<th>Virus/virus disease and acronym</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aphid:</strong></td>
<td></td>
</tr>
<tr>
<td><em>Amphorophora idaei</em> (large raspberry aphid)</td>
<td>Black raspberry necrosis virus (BRNV)</td>
</tr>
<tr>
<td><em>Aphis idaei</em> (small raspberry aphid)</td>
<td>Raspberry leaf mottle virus (RLMV)</td>
</tr>
<tr>
<td><em>Nasonovia ribisnigri, Hyperomyzus lactucae, Myzus persicae, Cryptomyzus ribis</em></td>
<td>Raspberry leaf spot virus (RLSV)</td>
</tr>
<tr>
<td></td>
<td><strong>Rubus yellow net virus (RYNV)</strong></td>
</tr>
<tr>
<td></td>
<td>Raspberry vein chlorosis virus (RVCV)</td>
</tr>
<tr>
<td></td>
<td>Gooseberry vein banding disease (GVBD)</td>
</tr>
<tr>
<td><strong>Nematode:</strong></td>
<td></td>
</tr>
<tr>
<td><em>Longidorus</em> species</td>
<td>Raspberry ringspot virus (RpRSV)</td>
</tr>
<tr>
<td><em>Xiphinema diversicaudatum</em></td>
<td>Tomato black ring virus (TBRV)</td>
</tr>
<tr>
<td></td>
<td><em>Arabis mosaic virus (ArMV)</em></td>
</tr>
<tr>
<td></td>
<td><em>Strawberry latent ringspot virus (SLRSV)</em></td>
</tr>
<tr>
<td><strong>Eriophyid mite:</strong></td>
<td></td>
</tr>
<tr>
<td><em>Cecidophyopsis</em> species</td>
<td>Blackcurrant reversion virus (BRV)</td>
</tr>
<tr>
<td><strong>Pollen-borne:</strong></td>
<td></td>
</tr>
<tr>
<td>No known vector</td>
<td>Raspberry bushy dwarf virus (RBDV)</td>
</tr>
</tbody>
</table>

**Results and Discussion**

**Planting of virus-tested stock plants**

Planting virus-infected material provides an infection source within the crop at the earliest possible time and when plants are most vulnerable to, and suffer the greatest effect from, infection; it allows the maximum time for virus spread within that crop. Planting virus-free stocks is therefore vital for satisfactory control of all the viruses. However, until the 1960s, growers were commonly planting material derived from diseased stock, so that viruses became widely distributed in planting stocks, often together with their vector. In Scotland, the development and introduction of a Certification Scheme for planting stock, based on material derived from plants tested and found free from important viruses and other diseases and pests, was the first Scheme to provide growers with the opportunity to break the cycle of perpetual infection (Jones, 1991). Subsequently, similar cane fruit stocks Schemes, based on the...
Scottish model, were introduced in other countries and this has been a major contribution to improved plant health and crop yield.

**Control of nematode-borne viruses**

The four nematode-transmitted viruses listed in Table 1 can cause serious damage and yield loss and occur commonly throughout Europe, especially Northern Europe. However, they are usually restricted in distribution to patches within crops. Each of these viruses, and their respective vector, have a very wide natural host range including many weed species and the viruses are transmitted through the seed of many of these species, often to a high incidence (Murant et al., 1996). *Rubus* species are commonly infected with these viruses but infection in *Ribes* species appears to be rare (Jones and McGavin, 1996). Although immunity to these viruses occurs in raspberry (Jones and McGavin, 1998), this is highly strain specific and is not effective in the field where several different strains can occur at a single site (Jones et al., 1989).

Effective control of these viruses in several different crop species has been achieved using soil fumigants prior to planting to kill viruliferous nematodes. Because the nematodes that occur beneath the fumigated zone will in time colonise this zone, effective control requires good weed control to prevent weed seedlings germinating from virus-infected seed and providing a virus source from which nematodes acquire virus to transmit to crop plants. Whilst these combined control measures have been effective for controlling RpRSV and TBRV in many crop species, control of ArMV and SLRSV, especially in long-term perennial crops, such as raspberry, has been less effective. This is because the vector, *X. diversicaudatum*, after acquiring these viruses, is able to retain and transmit them for up to 12 months or more. Therefore, when such nematodes colonise the initially sterile zone, they are still viruliferous even in the absence of virus-infected weed sources.

One possible future approach to control ArMV and SLRSV in perennial crops, is to engineer resistance using genes derived from the genome of these viruses. In a preliminary assessment of this approach, effective resistance to nematode inoculation with SLRSV was obtained in tobacco plants transgenic for some of the coat protein gene sequence of SLRSV (Kreiah et al., 1996).

**Control of aphid-borne viruses**

The large raspberry aphid, *Amphorophora idaei*, transmits four of the five important *A. idaei*-borne viruses infecting *Rubus* (Table 1). Although some insecticides are very effective in controlling *A. idaei* numbers on *Rubus*, they are not effective in decreasing significantly the four viruses it transmits (Taylor and Chambers, 1969; Jones, 1986).

No immunity to the four *A. idaei*-transmitted viruses (Table 1) has been detected in *Rubus* germplasm (Jones and Jennings, 1980) but several sources of strong resistance to *A. idaei* are known (Knight et al., 1959; Keep and Knight, 1967). In the UK, the introduction of such resistance into commercial raspberry cultivars has had a dramatic effect on the incidence of the four viruses it transmits (Jones, 1976; 1979; 1988). Indeed, observations in the UK for over 20 years has shown that crops of commercial *A. idaei*-resistant raspberry cultivars contained less than 5-10 % infection with *A. idaei*-transmitted viruses up to 16 years after planting, without the use of aphicides (Jones, 1988; A.T. Jones, unpublished data). Consequently, a major requirement for raspberry breeding programmes is resistance to *A. idaei*. However, the widespread and prolonged cultivation of raspberry cultivars with such resistance genes has created a strong selection pressure on the aphid to overcome such resistance. Five biotypes of *A. idaei* are now recognised in the UK and one or more of these biotypes are capable of colonising plants containing the *A. idaei*-resistance genes $A_1$ and $A_{10}$ (Birch and Jones, 1988; Jones et al., 2000).
Because no immunity to these *A. idaei*-transmitted viruses is known in *Rubus* germplasm, all raspberry cultivars are infectible with each of the four viruses but only some develop severe disease symptoms when infected with some of these viruses. For example, infection with RLMV or RLSV in raspberry cultivars sensitive to these viruses causes a severe disease, leaf spot mosaic, that makes plants unproductive within 3-4 years of infection. The basis for this sensitivity to infection is determined by single dominant genes termed, *Lm* for reaction to RLMV, and *Ls* for reaction to RLSV (Jones and Jennings, 1980). It is possible therefore for breeders to select progeny lacking these genes to produce plants tolerant to infection with these viruses.

The small raspberry aphid, *Aphis idaei*, transmits only RVCV that is now very common in crops in Europe. No sources of resistance to this aphid have been identified in *Rubus* germplasm but resistance to the virus has been identified in some *R. strigosus var. idaeus* material. Crosses between RVCV-infectible and -resistant material produced a significant number of progeny with high resistance/immunity to RVCV (Jennings and Jones, 1986). Although the precise mechanism of inheritance of this resistance remains undetermined, it seems that selecting RVCV-resistant material might not be difficult to achieve (Jennings and Jones, 1986).

As GVBD has been little studied, no information is available on the control of aphid-borne viruses of *Ribes* by insecticide applications, nor is resistance to GVBD reported in germplasm. The control of GVBD by breeding for resistance to the aphid vectors of GVBD seems remote because several different aphid species are reported as vectors (Table 1). However, as with other virus diseases, the planting of healthy stock away from sources of infection, roguing out infected plants, and the control of possible vector aphids are sensible precautions to minimise virus spread (Jones, 2002).

**Control of eriophyid mite-transmitted virus**

Reversion of blackcurrant is the most important disease of blackcurrant worldwide. The causal virus (BRV) is transmitted by the blackcurrant gall mite, *Cecidophyopsis ribis*, which is itself the most important pest problem in blackcurrant (Brennan, 1990; Jones, 2000). In the past, control of both of these organisms has been through roguing affected bushes and the control of mite numbers using acaricides. However, satisfactory chemical control of mites is difficult to achieve due to the fact that applications must coincide with mite dispersal from blackcurrant buds. This dispersal is determined by environmental conditions and by the position of the bud on the cane. When there are more than 5% galled plants in crops, further chemical control of spread is regarded as uneconomic. Breeding for resistance to *C. ribis* and/or BRV is therefore a major priority in blackcurrant breeding programmes (Brennan, 1990; Brennan et al., 1993).

Resistance, possibly immunity in many instances, to each of these organisms has been identified in *Ribes* germplasm. Gene *Ce* from gooseberry has been introduced into blackcurrant to give gall mite resistant plants (Knight et al., 1974). Additionally, *R. nigrum var. sibiricum*, *R. pauciflorum*, *R. petiolare* and *R. ussuriense* have also been used as donors for gall mite resistance, which, in these species, is determined by gene *P* (Anderson, 1971). The resistance conferred by gene *Ce* is much stronger than that of gene *P*, virtually preventing mite infestation altogether. In gene *P*-containing plants however, gall mites are initially able to infest buds that become necrotic inhibiting the further survival and reproduction of mites. In field trials, BRV is found in plants containing gene *P* (Pavlova, 1964; Jones et al., 1998a), suggesting that this resistance source is not very satisfactory for controlling BRV. By contrast, gene *Ce*-containing blackcurrant cultivars remained uninfected with BRV in field experiments using high inoculum pressure from viruliferous gall mites (Jones et al., 1998a).
Resistance, possibly immunity, to BRV has been identified in *R. cereum*, *R. dikushka* and *R. pauciflorum* (Pavlova, 1964; Brennan, 1990; Brennan et al., 1993). In field trials under high inoculum pressure of BRV, reversion-resistant blackcurrant cultivars failed to become infected even though such plants contained many galls (Jones et al., 1998a). Despite this, and because of the serious damage caused by gall mites as pests, the use of gene Ce that confers strong resistance to these mites, and consequently also to BRV, seems the best means of control.

However, recent studies on the molecular ecology of eriophyid mites on *Ribes* species in Europe indicate the occurrence of a larger number of *Cecidophyopsis* species than that known previously. Furthermore, it has shown the ability in nature of some species to colonise *Ribes* species assumed previously to support only one species (Fenton et al., 1995; 1996). These findings may have implications for the durability of the mite-resistant genes currently being deployed.

**Pollen-transmitted virus**

RBDV causes Yellows disease of *Rubus*, can induce severe crumbliness of fruit and, in association with aphid-borne viruses, causes ‘bushy dwarf disease’ leading to degeneration in plant vigour (Jones et al., 1996). It is currently regarded as the most widespread and important virus of *Rubus*. RBDV is transmitted between *Rubus* plants in the field only in association with flowers; no animal vector is reported (Jones et al., 1996). Because of its mode of spread, control is only possible either by growing healthy *Rubus* stocks away from infection sources, or by growing RBDV-resistant cultivars. Resistance to the common isolate of RBDV, that is prevalent wherever *Rubus* is grown, is present in many commercial raspberry cultivars and this resistance is determined by the single dominant gene, *Bu* (Jones et al., 1982; 1998b). This has provided effective control of such virus isolates for more than 40 years even under strong inoculum pressure. However, in more recent years, isolates of RBDV able to overcome gene *Bu* (termed resistance-breaking isolates, RB) have been identified in commercial raspberry crops in England and Wales, Northern Europe and Russia and such isolates were able to infect almost all *Rubus* germplasm tested (Jones et al., 1996). Control of these RB isolates is therefore a serious problem.

A possible approach to control RB isolates is engineering resistance using transgenes derived from the RBDV viral genome. Initial experiments using a tobacco model suggest that such an approach might be successful (Angel-Diaz et al., 1997). Attempts to produce and evaluate the resistance to RBDV of transgenic raspberry are being made currently in Scotland (Angel-Diaz et al., 1997) and in the USA (Martin and Mathews, 2001).

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**References**


Jones, A.T., McGavin, W.J. & Birch, A.N.E. 2000: Effectiveness of resistance genes to the large raspberry aphid, *Amphorophora idaei* Börner, in different raspberry (*Rubus idaeus*


Pavlova, N.M. 1964: [Possibilities of breeding blackcurrant varieties resistant to the bud gall mite.] Trudy prikladnoi Botanike, Genetekte i Selektii 36: 94-102. [in Russian]

Phytotoxicity of botryocides to several strawberry cultivars

Beata Meszka, Anna Bielenin
Research Institute of Pomology and Floriculture, 96-100 Skierniewice, ul. Pomologiczna 18, Poland

Abstract: Phytotoxicity effect of the main botryocides, thiram, tolylfluanid, procymidone, iprodione, fenhexamid and pyrimethanil, was observed in field trials on cvs. Selva, Elsanta, Elkat, Honeoye, Pegasus, Kent and Dukat in hot seasons. All tested fungicides caused some damage to green parts of plants, mostly leaves. Necrotic and chlorotic spots developed. The most severe damages to all tested cultivars were observed after tolylfluanid and iprodione sprays while procymidone, thiram and fenhexamid gave only slight phytotoxicity symptoms. Almost no damage occurred on cvs. Kent and Dukat and only slight damage (score 0.5-1) on the other cultivars.

Key words: strawberry, cultivars, fungicides, phytotoxicity

Introduction

Grey mould caused by Botrytis cinerea is the most important strawberry disease in Poland. Depending of season, it accounts for losses ranging from 10% to even 80% of the total yield (Bielenin et al., 2001). Usually several treatments (3-5) are needed during blossom time for control of disease. In hot seasons it was observed that some botryocides used in the control of grey mould can be phytotoxic to strawberry plants. Sokhi et al. (1990) noted on muskmelon that risk of russeting was increased by overdosage and by application at high temperature (over 25°C). Also stressed plants were more prone to phytotoxicity damage.

The aim of this work was the evaluation of the phytotoxicity effect of six popular in Poland botryocides (thiram, tolylfluanid, iprodione, procymidone, fenhexamid and pyrimethanil) on seven strawberry cultivars.

Material and methods

A field experiment was conducted at a private farm near Skierniewice in 2001 on seven cultivars of strawberries (Selva, Elsanta, Elkat, Honeoye, Pegasus, Kent and Dukat). Plots (each about 40 m²) were one-sided treated with each of botryocides: Pomarsol Forte 80 WG - Bayer AG (thiram), Euparen Multi 50 WG - Bayer AG (tolylfluanid), Rovral FLO 255 SC - Aventis S.A. (iprodione), Sumilex 500 SC - Sumitomo Chemical Company (procymidone), Teldor 500 SC - Bayer AG (fenhexamid) and Mythos 300 SC - Aventis S.A. (pyrimethanil). The strawberries were sprayed four times starting at the beginning of blossom and then every 5-7 days. A motor knapsack sprayer “Solo” with 600 l of liquid per 1 ha was used.

The evaluation of phytotoxicity of fungicides was made two weeks after the first application when severe symptoms occurred. A four grade score with: 0- no damage, 1- necrotic spots only on edges of leaves, 2- up to 30 % leaf surface covered with necrotic spots, 3- above 30 % leaf surface covered with necrosis (leaves and calyx strongly damaged) was used.
Results and discussion

In 1999, severe damage by some botryocides, mostly iprodione, was observed on several commercial strawberry plantations after application during hot weather. Also in 2001 when the field trial was conducted, high temperatures and dry conditions were favourable for the phytotoxicity effect. During the day of the first spray, the temperature reached 31.3°C (Fig. 1) and most of the phytotoxicity symptoms occurred after this treatment. Discoloration of leaves and calyx was observed already by the fifth day. This was before the second spray application. Tested fungicides, thiram, tolylfluanid, iprodione, procymidone, fenhexamid and pyrimethanil varied in their phytotoxicity to strawberries. Damage of plants was also strongly connected with cultivar. The most severe damage was caused by tolylfluanid and it varied between a score of 2-3 depending on the cultivar (Table 1). Phytotoxicity effect of tolylfluanid and fenhexamid have also been noted on fruit of sweet cherries (Stensvand and Borve, 1999).

Figure 1. Temperatures in seasons 1999 and 2001 during treatment against *Botrytis cinerea*.

In high temperature conditions in 2001 some cultivars (Elsanta, Selva and Pegasus) also showed high sensitivity to iprodione – with scores of 2 to 3 being recorded (Table 1). Similar high levels of phytotoxicity of iprodione was observed earlier in 1999 on Senga Sengana plantations.

Necrotic and brown-reddish spots developed on leaves of cultivars Selva, Elsanta and Pegasus, which were treated by pyrimethanil – score 2. The other fungicides, such as thiram, procymidone and fenhexamid, were only slightly phytotoxic and insignificant symptoms on cultivars Selva, Elsanta, Elkat and Pegasus (0.5-1 score) and no evidence of phytotoxicity on Honeoye, Kent and Dukat was observed (Table 1).
Table 1. Phytotoxicity of botryocides used in control of grey mould on strawberries in Poland in 2001

<table>
<thead>
<tr>
<th>Fungicides</th>
<th>Active ingredient and dose per 1 ha</th>
<th>Selva</th>
<th>Elsanta</th>
<th>Elkat</th>
<th>Honeoye</th>
<th>Pegasus</th>
<th>Kent</th>
<th>Dukat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pomrsol Forte 80 WG</td>
<td>thiram 4.0 kg</td>
<td>1</td>
<td>1</td>
<td>0.5</td>
<td>0</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Euparen Multi 50 WG</td>
<td>tolylfluanid 5.0 kg</td>
<td>2.5</td>
<td>2.5</td>
<td>3</td>
<td>2.5</td>
<td>2.8</td>
<td>2.8</td>
<td>2</td>
</tr>
<tr>
<td>Sumilex 500 SC</td>
<td>procymidone 1.5 l</td>
<td>1.5</td>
<td>1</td>
<td>0.5</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Teldor 500 SC</td>
<td>fenhexamid 1.5 l</td>
<td>1</td>
<td>1</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mythos 300 SC</td>
<td>pyrimethanil 2.5 l</td>
<td>2</td>
<td>2</td>
<td>X</td>
<td>X</td>
<td>1.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Rowral Flo 255 SC</td>
<td>iprodione 3.0 l</td>
<td>3</td>
<td>3</td>
<td>X</td>
<td>X</td>
<td>2</td>
<td>1.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

X = not tested
The presented results showed that all tested cultivars were sensitive to tolylfluanid and iprodione, when they were used in high temperature. In such condition only other botryocides like thiram, procymidone and fenhexamid can be used safely. Proper assortment of fungicides is also important for strawberry cultivations under plastic cover, where very high temperatures are often. Besides choice of chemicals also differences in reaction of cultivars should be respected. Differences in phytotoxicity of fungicides to some cultivars were also noted in other species (Wojdyła, 2000).

Conclusions

1. Tolylfluanid and iprodione can not be used in control of grey mould of strawberry in temperatures above 25°C. All tested cultivars can be damaged.
2. Selva and Elsanta were the most sensitive cultivars to all tested fungicides.
3. Thiram, procymidone and fenhexamid were the safest fungicides.

References

Overwintering of *Botrytis cinerea* in strawberry fields in Norway

Gunn Mari Strømeng, Arne Stensvand
The Norwegian Crop Research Institute, Plant Protection Centre, Høgskoleveien 7, 1432 Ås, Norway

**Abstract:** A survey on the overwintering of grey mould in strawberry fields in Norway was carried out during the spring of 2000 and 2001. The purpose was to find the most important sources of initial spring inoculum and to quantify the importance of sclerotia as spring inoculum. Plant material and soil were collected in five fields in different regions both years. The total estimated number of conidiophores produced per m² plant row ranged from 19 000 to 350 000, and from 0 to 16 000 between the plant rows. Senescing (partly necrotic) leaves, dead leaves, dead stolons and dead inflorescence stems were all important inoculum sources, but their relative importance varied greatly between the fields. Overwintered green leaves often turned necrotic during incubation and frequently developed high numbers of conidiophores. Mummified fruits and weeds were generally of minor importance because they were present in low numbers. Negligible amounts of inoculum were observed in straw mulch. Inoculum level in soil ranged from 0 to 20 000 conidiophores per 50 g dry weight soil. Conidiophores produced by sclerotia varied from 5 to 99% of the total inoculum. Sclerotia were found on the laminae and petioles of dead leaves, stolons and inflorescence stems (including pedicels), but appeared most frequently on the latter.

**Key words:** Grey mould, inoculum, conidiophores, sclerotia

**Introduction**

Grey mould, caused by the fungus *Botrytis cinerea* Pers. ex. Fr., is the most important disease in strawberry production in Norway. Repeated fungicide applications during flowering are necessary to reduce fruit rot, but results in detection of fungicide residues in fruits at harvest. Although residues are rarely above the residue limits set by the authorities, there is a need to find alternative strategies to control grey mould epidemics. Inoculum causing flower infections is to a large extent produced locally within the strawberry crop, and application of fungicides in autumn and spring has successfully suppressed initial inoculum of *B. cinerea* in the field during flowering (Jordan and Pappas, 1977; Sutton, 1991). The fungus overwinters either as mycelium or sclerotia in living or dead plant tissue. In addition, it may survive as sclerotia in soil. Spores (conidia) are produced on spore bearing hyphae (conidiophores) from the mycelium or the sclerotia. It is assumed that sclerotia are less vulnerable to fungicides than mycelium. If sclerotia are important for overwintering of the fungus, fungicide applications carried out after sclerotia formation in autumn or spring are likely to be less effective than if mycelium dominates as inoculum. In Ontario, Canada, overwintering plant material was investigated over two years in strawberry fields at three different locations, and it was concluded that mycelium in dead strawberry leaves was the most important initial inoculum in the field in the spring (Braun and Sutton, 1987). Sclerotia were of minor importance, and constituted only 1.8-7.0% of the total inoculum. These findings contrasted with observations in Scotland, where sclerotia were found abundantly on dead leaves and stolons of strawberries, and also in weeds and straw (Jarvis, 1962). However, the relative importance of the sclerotia was not reported from Scotland. This paper presents a survey
carried out with the purpose to find the relative importance of different strawberry plant parts, weeds, straw mulch, and soil as sources of initial inoculum in the spring, and furthermore, to find whether mycelium or sclerotia is the more important overwintering structure of *B. cinerea* in strawberry fields in Norway.

**Material and methods**

Plant material and soil were collected prior to flowering in the spring of 2000 and 2001 from five strawberry fields located in five different regions (counties) of Norway. The plantings were one to five years old, and planted with one of the following cultivars: Honeoye, Korona, Polka or Senga Sengana. In the fields in Oppland, Vestfold and Vest Agder counties, samples were taken from the same field both years, while in Rogaland and Møre og Romsdal counties samples were taken from different fields in the two years. Plant material and soil was taken from five randomly chosen squares in the plant rows and from five randomly chosen squares between the plant rows. The size of the squares was 25 x 25 cm. All aboveground plant material including weeds and straw within each square was collected. From each of the ten squares 0.2 litre of soil was collected from the upper 2-3 cm soil layer, to obtain a total sample of 2 litres. In cases where polyethylene was used as mulching material, soil was collected in the plant holes and on the side of the row.

The plant material was sorted into different categories, the most important being green leaf laminas, green petioles, senescing (partly necrotic) leaf laminas, senescing (partly necrotic) petioles, dead leaf laminas, dead petioles, dead stolons, dead inflorescence stems (peduncles and pedicels), weeds and straw. The total surface area of each category was measured using a leaf area meter. For three randomly chosen replicates of each category, leaf area was measured followed by incubation for five days in darkness at 20°C and 100% relative humidity. Conidiophores in the plant material were counted using a stereo microscope. It was distinguished between conidiophores produced by sclerotia or mycelium. The numbers given below for each category of plant material are mean of three replicates and are adjusted for total leaf area. They are presented as percentage of the total number of conidiophores.

The soil samples were air dried at 20°C for ten to twelve days. Three replicates of 50 g dry weight of each sample were incubated as a thin layer on screen plates. After five days of incubation, the soil was examined for conidiophores of *B. cinerea*.

**Results and discussion**

Both relative importance of different plant parts and plant residues as inoculum sources, and importance of sclerotia as inoculum source varied greatly between the fields in both years.

The estimated number of conidiophores per m² plant row including living and dead strawberry plant material ranged between 19 000 - 350 000 in 2000 and 20 000 - 322 000 in 2001. If including only dead plant material, the approximate numbers ranged between 4 900 - 227 000 in 2000 and 4 900 - 276 000 in 2001. These numbers are much higher than those reported by Braun and Sutton (1987) in Ontario. The difference may possibly be explained by a different climate and cultural practices, and the methodology used in the investigations. The estimated number of conidiophores per m² between the plant rows ranged between 0 - 16 000 in 2000 and 0 - 12 000 in 2001. Most of the inoculum (98% or more) was produced on strawberry plant material.

The relative importance of different strawberry plant parts sampled in the rows is shown in Table 1. Senescing leaf laminas were, with a few exceptions, an important source of inoculum. In Rogaland in 2000, senescing leaves (including petioles) constituted approxi-
mately 90% of the total inoculum, but was completely negligible the year after. Dead leaf laminas constituted by far the largest surface area of all categories. Despite this, they were not the major source of inoculum as they were in Ontario (Braun and Sutton, 1987). Their relative importance exceeded 50% in only one of ten samples. Dead petioles constituted from 0 to 45% of the total inoculum, and did in several fields/years produce more inoculum than the dead leaf laminas. Stolons were of minor importance in most fields, except in Oppland and Vest-Agder in 2000, where this category constituted more than 50% of the total inoculum. Dead inflorescence stems were, despite their relatively small surface area compared to other plant parts, important inoculum sources, and more or less all inflorescence stems investigated were infected by *B. cinerea*. Mummified fruits were a minor inoculum source in most fields, mainly because they were present in very low numbers. Nevertheless, in Vestfold and Møre og Romsdal in 2000, the relative amount of conidiophores from mummified fruits were approximately 14 and 23%, respectively, and in 2001, mummified fruits contained approximately 19% of the total inoculum in Vest Agder. Unidentifiable plant residues in the rows were assumed to be strawberry plant material, because of the limited amounts of weeds in the fields. Straw mulch was not included in this category. Residues were mainly stem fragments, probably both petioles, stolons and peduncles, but in Oppland in 2001 and Møre og Romsdal in 2000 small fragments of dead strawberry leaf laminas were also considerable. The relative importance of this category varied from less than 1% of the total inoculum to approximately 41%.

Table 1. Relative importance of different strawberry plant parts as source of inoculum of *Botrytis cinerea*, estimated from conidiophore counts and adjusted for leaf area. Samples were collected prior to flowering in 2000 and 2001 from overwintering strawberry plant material in five fields in five different counties of Norway.

<table>
<thead>
<tr>
<th>Plant parts</th>
<th>Conidiophores produced (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senescing leaf laminas</td>
<td>34.7</td>
</tr>
<tr>
<td>Senescing petioles</td>
<td>0.7</td>
</tr>
<tr>
<td>Dead leaf laminas</td>
<td>22.7</td>
</tr>
<tr>
<td>Dead petioles</td>
<td>3.4</td>
</tr>
<tr>
<td>Dead stolons</td>
<td>32.7</td>
</tr>
<tr>
<td>Dead inflorescence stems</td>
<td>1.8</td>
</tr>
<tr>
<td>Mummified fruits</td>
<td>0.5</td>
</tr>
<tr>
<td>Unidentifiable residues</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Sporulation of *B. cinerea* was counted on leaves that were green at the time of sampling, but became necrotic during the incubation period. On these leaves, both fully expanded and partly expanded, large numbers of conidiophores were produced. In four of the samples, green leaves constituted more than 50% of the total inoculum. The reason why green leaves are left out of Table 1 is that they were not a source of sporulation at the time of sampling, and that storage and incubation accelerated senescence in the leaves.
Weeds were not abundant in the fields, and constituted less than 2% of the total inoculum in the fields. Therefore, additional overwintered weeds were collected at random within the fields and from the surrounding edges in 2001. Abundant sporulation of \textit{B. cinerea} was observed in senescent and dead weeds. This means that weeds may be an important inoculum source in the fields if not properly controlled. Straw mulch was present in three fields in 2000 and two fields in 2001, and straw samples from these fields were examined for conidiophores. Only four conidiophores were observed in straw.

Conidiophores produced by sclerotia varied from approximately 5 to 99% of the total inoculum production (Table 2). In five of the samples, sclerotia produced more than 75% of the total inoculum, and these results are very different from those obtained in Ontario, where it was established that sclerotia had little importance as spring inoculum (Braun and Sutton, 1987). Sclerotia were found in dead plant residues, but never in necrotic areas of senescing plant parts. Most inoculum on inflorescence stems originated from sclerotia. Sclerotia very often occurred in clusters, and the size of each sclerotium varied from less than 1 mm to more than 10 mm in length. In mummified fruits, single sclerotia were usually observed in between the achenes. In some cases conidiophores arised from mycelium in fruit mummies.

The estimated number of sclerotia per m² plant row ranged from approximately 95 to 780 in 2000, and from 980 to 5700 in 2001. Climatic conditions are probably responsible for most of these variations. The age of the crop may possibly influence the number as well, as a larger amount of plant residues from year to year makes a larger surface area available for sclerotia formation. High numbers of sclerotia were observed on dead overwintered inflorescence stems of weeds (dicots) collected at random in the fields in 2000.

Table 2. Production of conidiophores of \textit{Botrytis cinerea} from sclerotia in percentage of total production. Samples were collected prior to flowering in 2000 and 2001 from different overwintering strawberry plant material in five fields in five different counties of Norway.

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>Senescing leaf laminas</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Senescing petioles</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>–</td>
<td>0.0</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.0</td>
</tr>
<tr>
<td>Dead leaf laminas</td>
<td>0.0</td>
<td>16.6</td>
<td>0.0</td>
<td>98.2</td>
<td>100</td>
<td>–</td>
<td>38.9</td>
<td>36.9</td>
<td>–</td>
<td>20.6</td>
</tr>
<tr>
<td>Dead petioles</td>
<td>0.0</td>
<td>99.8</td>
<td>43.3</td>
<td>100</td>
<td>99.4</td>
<td>100</td>
<td>20.8</td>
<td>94.7</td>
<td>–</td>
<td>34.4</td>
</tr>
<tr>
<td>Dead stolons</td>
<td>12.5</td>
<td>100</td>
<td>0.0</td>
<td>–</td>
<td>100</td>
<td>100</td>
<td>0.0</td>
<td>91.1</td>
<td>100</td>
<td>0.0</td>
</tr>
<tr>
<td>Dead inflorescence stems</td>
<td>89.9</td>
<td>100</td>
<td>98.5</td>
<td>100</td>
<td>–</td>
<td>100</td>
<td>65.1</td>
<td>98.6</td>
<td>99.9</td>
<td>43.4</td>
</tr>
<tr>
<td>Mummified fruits</td>
<td>0.0</td>
<td>98.8</td>
<td>0.0</td>
<td>100</td>
<td>–</td>
<td>100</td>
<td>–</td>
<td>100</td>
<td>100</td>
<td>8.0</td>
</tr>
<tr>
<td>Unidentifiable residues</td>
<td>0.0</td>
<td>99.6</td>
<td>96.8</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>0.0</td>
<td>96.2</td>
<td>98.3</td>
<td>0.0</td>
</tr>
<tr>
<td>Percent conidiophores from sclerotia of total inoculum</td>
<td>5.7</td>
<td>76.2</td>
<td>12.8</td>
<td>24.7</td>
<td>99.1</td>
<td>87.5</td>
<td>4.6</td>
<td>95.4</td>
<td>89.0</td>
<td>13.1</td>
</tr>
</tbody>
</table>
The number of conidiophores in 50 g dry weight soil ranged between 0 and 90 in 2000, and between 0 and 210 in 2001. Conidiophores were produced by sclerotia or by mycelium on small pieces of plant residues. The number of sclerotia found in soil was generally low (Table 3), and these results agree with those of Braun and Sutton (1987). In Vestfold and Møre og Romsdal, no sclerotia were observed in any of the years. The Oppland and Rogaland fields had 2.7 viable sclerotia per 50 g dry weight soil in 2000, and in the following year the corresponding number in the Oppland field was 3.7 sclerotia. These numbers were the highest recorded during the survey. In Ontario, the numbers of sclerotia in soil ranged from 0 to 1 (Braun and Sutton 1987). Due to a much higher incidence of sclerotia in plant residues in the present study, it was expected that the numbers would differ even more. Physical conditions, such as water content, and attack by other microorganisms may influence the viability of sclerotia in soil.

Table 3. Number of sporulating sclerotia and number of conidiophores of *Botrytis cinerea* counted in 50 g dry weight soil. Conidiophores originated from either sclerotia or from mycelium in small fragments of plant tissue. Soil samples were collected in five strawberry fields in five different regions of Norway prior to flowering in 2000 and 2001.

<table>
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<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of sclerotia</td>
<td>2.7</td>
<td>3.7</td>
<td>0.0</td>
<td>0.0</td>
<td>2.7</td>
<td>1.0</td>
<td>1.3</td>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Conidiophores from sclerotia</td>
<td>59.0</td>
<td>193.3</td>
<td>–</td>
<td>–</td>
<td>81.0</td>
<td>51.0</td>
<td>11.0</td>
<td>32.0</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Conidiophores from mycelium</td>
<td>0.7</td>
<td>11.3</td>
<td>15.7</td>
<td>0.0</td>
<td>1.3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.3</td>
<td>0.0</td>
<td>1.3</td>
</tr>
</tbody>
</table>

The present study has shown that most inoculum of *B. cinerea* are produced by senescing and decomposing strawberry plant material in the field, but weeds, if abundant, may be an important source of inoculum as well. Straw mulch and soil seem to be of minor importance. Sclerotia were important overwintering structures in several fields/years. Assuming that sclerotia are more resistant to fungicides than mycelium, this probably reduces the opportunity for effective fungicide control carried out in autumn and spring to reduce the inoculum during flowering. Time of sclerotia formation in the autumn will influence timing of possible control measures, and thus further investigations on interactions between sclerotia and fungicide control are needed.

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References


Induced resistance to *Phytophthora* diseases in strawberry

Håvard Eikemo, Arne Stensvand, Anne Marte Tronsmo

*The Norwegian Crop Research Institute, Plant Protection Centre*

*Høgskoleveien 7, N-1432 Aas, Norway*

**Abstract:** Two putative elicitors (Bion® and chitosan) showed effect against crown rot (*Phytophthora cactorum* (Leb. & Cohn) Schrot) in strawberry in preliminary experiments, and were tested further to investigate the effect of different concentrations, the possible duration of the resistance response and to compare the effect with that of fungicide treatment (phosetyl-Al). The experiments took place in either a greenhouse or a growth chamber. The effect of both Bion and chitosan was enhanced when the time between treatment and inoculation was prolonged from 2 to 20 days. Bion showed increasing effect when the concentration was raised from 50 to 1000 µg per plant, while chitosan seemed to have a negative effect when the concentration exceeded 250 µg per plant. There were no significant differences in disease score between phosetyl-Al (0.3 % solution), Bion (100 µg/plant) and chitosan (100 µg/plant) treatments when applied 15 or 5 days before inoculation. The effect of Bion and chitosan was also tested against red stele (*P. fragariae* Hickman var. *fragariae*) in strawberry in a growth chamber. Both compounds were applied in 2 concentrations (50 or 250 µg/plant) at 4 different times (either 5, 10, 20 or 40 days before inoculation), and phosetyl-Al (0.3 %) was included as a control. Chitosan had no effect at all, while phosetyl-Al and all treatments with Bion reduced the severity of the disease significantly. There was no significant difference between the effect of 250 µg Bion and phosetyl-Al when both compounds were applied at the same time.

**Keywords:** Bion, chitosan, crown rot, elicitors, red stele

**Introduction**

Crown rot of strawberry caused by *Phytophthora cactorum* (Leb. & Cohn) Schrot. was first reported from Germany in 1952 (Deutschmann, 1954), and has since been detected in most parts of the world. It was discovered in Norway in 1992, and has since then been found in more than 100 different locations, distributed over most parts of the country. The resting spores (oospores) of the fungus can survive in soil for many years, and there are no practical means of eliminating *P. cactorum* from the soil if a field has become infested. In Norway, the only chemical product allowed against crown rot is phosetyl-Al. Use of disease free planting material, improved drainage in the soil and growing on raised beds will also reduce the attack. One important alternative to chemical control and cultural measures is the use of resistant cultivars, but most cultivars with this quality do not have other, necessary qualities (colour, flavour, size, shelf life, etc.) that are essential in commercial strawberry production. Another possible approach might be to exploit induced resistance. In two preliminary experiments (H. Eikemo, unpublished data), several compounds (of both biotic and abiotic origin) were tested as putative elicitors of disease resistance against *P. cactorum* in strawberry. The results showed varying effects of the putative elicitors, but two of them (Bion and chitosan) gave consistent positive effects. In the present work, Bion and chitosan was tested further to investigate the effect on crown rot and red stele (*Phytophthora fragariae* var. *fragariae*) in strawberry.
Materials and methods

Elicitors and treatment
The two products used as putative resistance elicitors in these experiments were Benzo (1,2,3) thiadiazole-7-carbothioic acid S-methyl ester (Bion WG50; Novartis Ltd., Basel, Switzerland) and chitosan (Fluka Chemie AG, Buchs, Switzerland). The chitosan was dissolved in 0.1% acetic acid in a stock solution of 5 mg ml\(^{-1}\), and diluted to the desired concentration with \(\text{dH}_2\text{O}\) on the day of treatment. Bion was made as a stock solution of 10 mg d.w. ml\(^{-1}\) in \(\text{dH}_2\text{O}\) and diluted with \(\text{dH}_2\text{O}\). Bion is formulated as a 50% water dispersible granulate, so the amount of active ingredient (Benzothiadiazole) was half the dry weight. In all solutions, 0.01% Triton X-100 was added as a dispersant). Both elicitors were sprayed onto the crown and lower part of the plants with a hand-powered sprayer, and each plant always received 1 ml.

Crown rot (\(P.\) cactorum)
Based on results from preliminary experiments, two new experiments were designed, focusing on time and dosage response of Bion and chitosan, and compared to the effect of the fungicide phosphetyl-Al (product: Aliette WG 80, Aventis CropScience, Lyon, France). In all experiments, cold stored plants of the susceptible cvs. Zephyr or Polka were used. Cold stored plants are known to be very susceptible to crown rot (Pettitt and Pegg, 1994; Eikemo et al., 2001) and allow inoculation without wounding the rhizome.

In the time response study, plants were treated with one concentration (100 \(\mu\)g d.w. per plant, containing 0.01% Triton X-100) of either Bion or chitosan 20, 10, 4 or 2 days before inoculation. The delay was not extended beyond 20 days because of the necessity to inoculate the plants soon after cold storage (Pettitt and Pegg, 1994). In the dosage response study, four dosages (10, 50, 250 and 1000 \(\mu\)g a.i. per plant) were applied 2 days before inoculation. In this experiment, the plants were inoculated 17 days after cold storage. To compare the effect of Bion and chitosan to Aliette, plants were treated at two time points (20 and 5 days before inoculation) with either 100 \(\mu\)g a.i. Bion or chitosan per plant or 5 ml 0.3% phosphetyl-Al solution.

The plants were inoculated by carefully spraying 2 ml of a \(7\times10^4\) zoospore suspension of \(P.\) cactorum containing a mixture of two isolates onto the crowns with a pipette. Plants that died during the first week after inoculation were scored 8, and the plants that died during the second, third or fourth week were scored 7, 6 or 5, respectively. After four weeks the crowns of the remaining plants were bisected longitudinally and scored from 4 to 1, based on the degree of necrosis (Bell et al., 1997). In the time and dosage response studies, 20 plants were inoculated and 5 were non-inoculated controls in each of two experiments. In the experiment where Bion, chitosan and phosphetyl-Al were compared, 30 plants were inoculated and 5 were non-inoculated controls of each treatment. In addition, untreated plants and plants treated with 0.01% Triton X-100 were used as controls. Before and during experiments, plants were kept in a greenhouse or in a growth chamber at 20 °C, with a 16-hour photoperiod. Artificial light was provided by high-pressure sodium lamps (SON/T, approximately 130 \(\mu\)E s\(^{-1}\) m\(^{-2}\)).

Red stele (\(P.\) fragariae var. fragariae)
The plants used in this experiment were of cv. Alexandria (\(Fragaria vesca\) L.), which are often used as test plants when screening plant material for red stele infections. Plants were propagated from seed and grown for one month before start of the experiment. Bion and chitosan were used in 2 concentrations (50 or 250 \(\mu\)g per plant). Plants were treated with Bion 40, 20, 10 and 5 days before inoculation while still in plug trays. In addition to non-inoculated and untreated, inoculated controls, plants treated with the fungicide phosphetyl-Al five days before inoculation were also included. The plants were potted in 10 cm pots (two
plants in each) in a 1:4 mixture of sand and peat. When potted, five 1 cm$^2$ discs of V8 medium with mycelium of *P. fragariae* var. *fragariae* (grown for 3 wks) were placed close to the roots of each plant. For each treatment 20 plants were inoculated, and 4 plants were non-inoculated controls. The experiment was organised in a randomised block design. Disease was recorded as fresh weight (FW) 6 and 8 wks after inoculation (10 plants from each treatment each time). Before and during experiments, plants were kept in a growth chamber at 15 °C, with a 16 hour photoperiod. Artificial light was provided by high-pressure sodium lamps (SON/T, approximately 200 µE s$^{-1}$ m$^{-2}$).

**Results**

The results of these experiments showed that the effect of both Bion and chitosan on crown rot was increased when the time between treatment and inoculation was prolonged (Fig. 1), and all treatments resulted in a significantly ($P < 0.01$) lower disease score compared to the control. Bion showed increasing effect when the concentration was raised from 50 to 1000 mg per plant, while chitosan seemed to have a negative effect when the concentration exceeded 250 mg per plant (Fig. 2). All treatments with Bion and the three lowest concentrations of chitosan gave significantly ($P < 0.01$) lower disease score compared to the control. Comparison to Aliette (Fig. 3) showed that all three compounds reduced the disease score similarly, and all treatments lowered the disease score significantly ($P = 0.01$). When plants were inoculated with *P. f. fragariae*, chitosan had no effect, while Bion reduced the disease score, especially in the highest concentration (Tab. 1). The fresh weight of plants treated with chitosan (all treatments) was similar to the inoculated control. Both Bion (all treatments) and phosetyl-Al gave increased FW compared to the inoculated control, but the FW was significantly ($P < 0.01$) lower than for the uninfected plants both 6 and 8 wks after inoculation.

![Figure 1. Disease score for strawberry plants pre-treated with Bion or chitosan at four different times before inoculation, compared to inoculated control. Numbers are means of 4 blocks in each of 2 experiments, and different letters indicate significant difference ($P \leq 0.05$) according to Duncan’s multiple range test.](image-url)
Figure 2. Disease score for strawberry plants pre-treated with four concentrations of Bion or chitosan two days before inoculation, compared to inoculated control. Numbers are means of 4 blocks in each of 2 experiments and different letters indicate significant difference ($P \leq 0.05$) according to Duncan’s multiple range test.

Figure 3. Disease score for strawberry plants pre-treated with Aliette, Bion or chitosan 5 or 20 days before inoculation, compared to inoculated control. Numbers are means of 6 blocks (5 plants in each) and different letters indicate significant difference ($P \leq 0.05$) according to Duncan’s multiple range test.

**Discussion**

These experiments showed that treatments with Bion or chitosan may be a way to enhance tolerance to crown rot in strawberry cultivars. Bion also increased resistance to red stele, and may be a future alternative to Aliette in controlling both diseases. Testing the effect of Bion
Table 1. Results from inoculation of strawberry plants (Fragaria vesca L., cv. Alexandria) with Phytophtora fragariae var. fragariae at different times after treatment with two putative defence elicitors and one fungicide (phosetyl-Al; Aliette 80 WG), shown as fresh weight (FW) \(^w\) 6 and 8 wks after inoculation.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>FW(g)</th>
<th>6 wk (^w)</th>
<th>8 wk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bion 50 µg</td>
<td>5 days</td>
<td>3.46 c</td>
<td>2.99 e</td>
</tr>
<tr>
<td></td>
<td>10 days</td>
<td>5.04 b</td>
<td>6.35 c</td>
</tr>
<tr>
<td></td>
<td>20 days</td>
<td>3.49 c</td>
<td>4.00 de</td>
</tr>
<tr>
<td></td>
<td>40 days</td>
<td>2.81 c</td>
<td>4.32 d</td>
</tr>
<tr>
<td>Bion 250 µg</td>
<td>5 days</td>
<td>4.68 b</td>
<td>8.37 a</td>
</tr>
<tr>
<td></td>
<td>10 days</td>
<td>3.42 c</td>
<td>5.86 c</td>
</tr>
<tr>
<td></td>
<td>20 days</td>
<td>3.72 c</td>
<td>6.18 c</td>
</tr>
<tr>
<td></td>
<td>40 days</td>
<td>5.38 b</td>
<td>6.56 bc</td>
</tr>
<tr>
<td>Chitosan 50 µg</td>
<td>5 days</td>
<td>1.02 d</td>
<td>1.11 f</td>
</tr>
<tr>
<td></td>
<td>10 days</td>
<td>1.03 d</td>
<td>0.68 f</td>
</tr>
<tr>
<td></td>
<td>20 days</td>
<td>0.85 d</td>
<td>0.74 f</td>
</tr>
<tr>
<td></td>
<td>40 days</td>
<td>1.44 d</td>
<td>1.44 f</td>
</tr>
<tr>
<td>Chitosan 250 µg</td>
<td>5 days</td>
<td>1.18 d</td>
<td>0.90 f</td>
</tr>
<tr>
<td></td>
<td>10 days</td>
<td>0.96 d</td>
<td>1.00 f</td>
</tr>
<tr>
<td></td>
<td>20 days</td>
<td>0.74 d</td>
<td>0.88 f</td>
</tr>
<tr>
<td></td>
<td>40 days</td>
<td>1.08 d</td>
<td>0.89 f</td>
</tr>
<tr>
<td>Phosetyl-Al</td>
<td>5 days</td>
<td>5.38 b</td>
<td>7.60 ab</td>
</tr>
<tr>
<td>Control (water)</td>
<td>Inoc.</td>
<td>0.89 d</td>
<td>0.78 f</td>
</tr>
<tr>
<td></td>
<td>Non-inoc.</td>
<td>6.81 a</td>
<td>8.64 a</td>
</tr>
</tbody>
</table>

\(^w\) Means followed by the same letter are not significantly different (\(P \leq 0.05\)) according to Duncan’s multiple range test.

\(^x\) Half of the plants (10 plants) were removed 6 wks after inoculation and the other half after 8 wks, and all the aboveground plant material was used to measure the fresh weight.

and chitosan on P. cactorum in vitro showed that Bion had no fungistatic effect while chitosan reduced fungal growth when the concentrations exceeded 50 mg/ml (H. Eikemo, unpublished data). Similar effects of Bion have been shown for other diseases in various hosts. For powdery mildew on wheat, treatment with the elicitor Bion 4 or 7 days before inoculation decreased the amount of infected leaf area more than treatment one day before inoculation (Görlach et al., 1996). In apple, treatment with Bion has been shown to increase resistance to fire blight and increase the levels of two defence related enzymes (Brisset et al., 2000). All these experiments were performed under controlled climatic conditions, and an important question is whether the effect will be similar under field conditions or not.

References


Possibilities for effective control of *Convolvulus arvensis* with bentazon in black currant

Jerzy Lisek
Research Institute of Pomology and Floriculture, Department of Fruit Crop Management and Plant Nutrition, Pomologiczna 18 Str., 96-100 Skierniewice, Poland

Abstract: Control of *Convolvulus arvensis* (field bindweed) on black currant commercial plantations is difficult with mechanical, biological as well as chemical methods. Promising results in controlling this species were obtained following the use of bentazon (Basagran 600 SL). Foliar treatments at two rates: 1.2 and 1.8 kg ha⁻¹ of bentazon with mineral oil, resulted in successful control of bindweed when the tested herbicide was applied at the beginning or in the middle of May. At the time of treatment weed shoots were 15-20 cm long. Bentazon was safe for black currant plants when applied with precautionary measures and with a sprayer fitted with protective shields. Injuries, in the form of necrotic spots, were seen only on the currant leaves sprayed with the herbicide.

Key words: *Convolvulus arvensis*, black currant, bentazon, weeds, integrated fruit production, herbicides

Introduction

*Convolvulus arvensis* L. (field bindweed) competes with soft fruit bushes, as well as other weed species, for water and nutrients, but most importantly it reduces machine harvest efficiency (Cianciara, 1987). Biological control with the host-specific fungal pathogens – *Stagonospora convolvuli*, *Erysiphe convolvuli*, offers good prospects for fruit production in the future (Abu Irmaileh and Al Raddad, 1999; Müller-Schärer et al., 1999). Field bindweed has a deeply penetrating taproot and numerous root stolons covered with buds, therefore both mechanical and chemical control is difficult. The soil acting herbicide dichlobenil, used in standard production, is not suitable for Integrated Production due to its persistence in the soil. When glufosinate ammonium is used as a foliar treatment, the bindweed quickly regrows. Glyphosate, MCPA or dicamba treatments are not safe enough for black currant and cause serious injuries to the bushes. Oxadiazon (Ronstar 25 EC) controls bindweed efficiently and is safe for currants but it is neither registered nor sold in Poland at present (Cianciara, 1987). Growers need a herbicide for effective control of *Convolvulus arvensis*. The aim of investigations was to check possibilities of controlling bindweed with bentazon.

Bentazon undergoes quick biodegradation in the soil and is not dangerous for the environment (Thomson, 1993). This herbicide is used first of all for weed control in peas (*Pisum sativum*) and dwarf bean (*Phaseolus vulgaris*) (Klaassen et al., 1988; Jensen, 1992). The results obtained with bentazon in potato (*Solanum tuberosum*), pepper (*Capsicum annuum*), cowpea (*Vigna unguiculata*), azalea (*Rhododendron* sp.) and green liriope (*Liriope muscari*) show specific cultivar response (Derr and Appleton, 1989; Love and Haderlie, 1991; Wolff et al., 1992; Harrison and Fery, 1993). Additives (surfactants and oils) to bentazon improved weed control (Eberlein et al., 1992; Al Khatib et al., 1995). Bentazon with mineral oils is recommended for *Epilobium adenocaulon* (perennial weed) control in orchards (Lisek, 1997).
Materials and methods

The biological effectiveness of bentazon (as Basagran 600 SL, BASF) containing 600 g l⁻¹ bentazon with the adjuvant Atpolan 80 EC (containing 76% of paraffin oils) was evaluated in field trials in Skierniewice (Central Poland) in 2000-2001. The test herbicide was applied at two rates: 1.2 and 1.8 kg ha⁻¹, and the adjuvant at the rate of 1.5 l ha⁻¹. Treatments were conducted in early or mid-May when bindweed shoots were 15-20 cm long and before they started to climb black currant bushes. At the time of treatment weeds were growing actively. Plants of the black currant cultivars Titania, Ojebyn and Ben Lomond were two, six or ten years old. Bentazon was applied with a precision plot sprayer, provided with a lance and protective shield, at a spray volume rate of 300 l ha⁻¹, at 0.2 MPa pressure. At the time of spraying the bindweed plants covered from 20 to 85% of the soil surface around the bushes. The herbicide was applied in 0.5-1 m wide bands on both sides of each row of bushes in 30 or 50 m² plots. The experiments were designed in randomised blocks with three or four replications.

Results and discussion

The symptoms of herbicide action were clearly visible three to seven days after the treatment. Bindweed leaves progressively turned yellow and necrotic from the top of the shoots. Decay of the weeds took 2-3 weeks. The average effectiveness of bentazon used to control bindweed at the rates of 1.8 kg and 1.2 kg a.i. per ha was 85 and 72%, respectively. Regrowth from burned bindweed plants was observed in late July. Regrowth levels of 9 and 15% corresponded to the higher and lower rates of bentazon application, respectively.

The degree of safety of bentazon treatment for black currant bushes was satisfactory. Necrotic spots were observed only on the lower leaves unintentionally sprayed with the herbicide, which composed from 1 to 3% of total leaf number. No negative influence on the growth and yield of the bushes was visible. The safety of currants was not related to the age of bushes or cultivar.

Bentazon, especially at the lower rate, gave poorer bindweed control than oxadiazon at the rate of 1.25 kg ha⁻¹, which burned nearly 100% of this weed (Cianciara, 1987). Both herbicides need protective shields during their application in May. Regrowth of bindweed after bentazon is faster than after oxadiazon at the above-mentioned dose (5-6% three months after the treatment), but oxadiazon shows soil activity which makes it unsuitable for Integrated Production. In comparison with herbicides used by some growers in practice (glyphosate, MCPA or dicamba), bentazon is more useful on plantations, because it acts faster and is safer for black currant bushes. Decay of bindweed treated with a mixture of MCPA (0.75 kg ha⁻¹) and dicamba (0.05 kg ha⁻¹) on commercial plantations takes on average 4 weeks. This mixture controls bindweed in 75-80% but sometimes seriously damages the bushes.

Injury caused by bentazon treatment were influenced by the time of application and weather conditions rather than the age of bushes and cultivar. It is possible that the differences between the currant cultivars in that respect were not obvious because the bushes were protected before herbicide spraying. Different response to bentazon in potato, pepper, cowpea or azalea was visible after treatments carried out without protecting the plants (Derr and Appleton, 1989; Love and Haderlie, 1991; Wolff et al., 1992; Harrison and Fery, 1993).

The results obtained in the experiments described here should be of interest to fruit growers. In the future, the use of bentazon should be combined with biological methods of controlling bindweed.
References


Use of natural oils in protection of **Rubus** and **Ribes** crops

**C. Cabaleiro, J. Garcia-Berrios, E. Carcelen**

*Departamento de Producción Vexetal, Universidade de Santiago de Compostela, Campus de Lugo s/n 27002 Lugo, Spain*

**Abstract:** Mineral, plant and fish oils were evaluated for phytotoxicity to raspberry and blackcurrant and for control of blackberry powdery mildew. Seven treatments were applied at weekly intervals to young raspberry potted plants kept in greenhouse; oils were applied as 0.25, 0.5, 1 and 2% sprays. Assessments were done 2 weeks after the last spray. Although plants showed some deterioration, concentrations up to 1% can be considered sure. Four years old blackberry plants grown in the open field were sprayed with the same oils at 1 and 2%; five treatments were applied at intervals of 15 days. Some leaf drop and some characteristic leaf spots and leaf border necrosis occurred after the third treatment. Control of blackcurrant powdery mildew (*Sphaerotheca mors-uvae*) was significantly better than water control and colloid sulphur; powdery mildew was controlled after the first treatment and during all summer with 5 sprays applied at intervals of 15 days.

**Key words:** oils, powdery mildew, phytotoxicity, raspberry, blackberry

**Introduction**

The efficacy of oils for the control of fungal diseases of plants was reviewed by Calpouzos many years ago (1966). Mineral oils have been the most widely used because of their known activity against insects and acari (Hesler and Plapp, 1986); they are commercially available and have been tested against Sigatoka leafspot of banana (caused by *Mycosphaerella musicola*) and other fungal diseases (Horst et al., 1992; Dell et al., 1998; Wicks et al., 1999; McGrath and Shishkoff, 2000). In the last decade some studies have been published about the activity of plant oils on diseases caused by powdery mildews and leaf spots (Northover and Schneider, 1993, 1996; Osnaya and Schlösser, 1998). Plant oils but also fish oils are natural products composed of fatty acid esters of glycerol; their use as fungicides as a natural alternative to synthetic fungicides would be especially attractive to home gardeners (Horst et al., 1992; Osnaya and Schlösser, 1998) and producers of organically grown products because refined oils are now readily available and safe for human consumption. They could be also interesting to berry growers because they have long period of harvest that, in many cases, prevents the use of fungicides. Calpouzos (1966) summarised the advantages of using oils for the control of plant diseases as providing good control at very low dosages, excellent spreading and sticking properties on leaf surfaces, low cost and little or no toxicity to animals and auxiliary organisms; the main disadvantage of oils is being phytotoxic to some crops.

Since 1999 our group is working with mineral, plant and fish oils as contact products against different pests and pathogens of grapevine and fruit shrubs. Our first objective before using oils against any pathogen on raspberry and blackberry plants was to check the phytotoxic effects. In growth chamber, glasshouse and open air assays with oils sprayed on grapevine plants phytotoxicity did not occur (Silvarrey et al., 2000). Control of grapevine powdery mildew (*Oidium tuckeri*) was excellent in our first assays in controlled conditions (Silvarrey et al., 2000). Powdery mildew (*Sphaerotheca mors-uvae*) is the only fungal pathogen we have observed in blackcurrant in our conditions; the infections start close to harvest and although berries do not show disease symptoms, if mildew is not controlled young shoots are strongly damaged.
Material and methods

Spray materials and application methods
Three different oils were examined; the mineral oil was Sunspray ultrafine (85%), a paraffin oil of high purity (Agrichem, S.A.); the plant oil was Codacide (Agrodan, S.A.), an emulsified oil based on polyethoxylated esters of rapeseed (Brassica napus L.) with a 95% of canola oil (Agrodan, S.A). The fish oil AF121 (AFAMSA, S.A.) is a refined oil with 0.2º of acidity used in alimentary industry; it was mixed with 10% Tween 20® as a surfactant. Oils were applied as emulsions in distilled water using separate hand-held aerosol sprayers for each type of oil; sprays were applied in order of increasing concentration of oils. The fungicide used in the powdery mildew assay was Spersul (Zeneca), a colloid sulphur (80%) applied as a suspension in distilled water.

Phytotoxicity to Raspberry
One hundred twelve raspberry plants (cultivar Willamette) developed from root cuttings were grown in a greenhouse in 400 ml containers. Three weeks before the first spray was applied the plants were pruned leaving only one sprout per pot. A completely random experimental design was used with 8 plants per treatment. The three oils were applied at four concentrations (0.25, 0.5, 1 and 2%); distilled water and Tween 20® (0.2%) were used as controls. The emulsions were sprayed on to plants keeping the sprayers approximately 30 cm apart from the plants; pots were temporarily removed from their places in the greenhouse to prevent spray drift and cross-contamination of treatments and then returned to their positions. Plants were sprayed weekly during seven weeks and data were collected two weeks after the last spray. The impact of sprays on phytotoxicity was determined by recording the number of leaves and sprouts of each plant and the length of shoots; a general condition/colour scale (1-5) was established to qualify the plants:
- 1, plants dead or almost, leaf drop, necrosis.
- 2, plants showing pale green colour, old leaf drop, leaf necrosis, wilting
- 3, plants discoloured or presenting necrotic spots or leaf border necrosis
- 4, plants looking quite healthy but pale green, some leaf curling
- 5, plants looking health, bright green colour, erected sprouts

Data were subjected to analysis of variance (SPSS 9.0). If treatment differences were significant, differences between oil treatments and controls were further explored using Tukey’s HSD. Regression analysis was performed for concentration differences.

Control of powdery mildew and phytotoxicity to blackcurrant
Four years old blackcurrant plants growing in the open field were checked during spring for the presence of powdery mildew (Sphaerotheca mors-uvae). Eighty branches with sprouts showing about the same area infected with powdery mildew were selected from ten plants and treatments were assigned randomly to groups of 10 branches. Branches were sprayed separately (covering the rest of the plant with a plastic bag) every fortnight with the mentioned oils at concentrations of 1 and 2%; distilled water and Spersul at 4.4 g/l were used as controls. Five sprays were applied during the summer of 2000. Every fortnight and before the next treatment was applied, 4 leaves from treated sprouts were examined and the percentage of leaf area showing mycelia and conidia of the fungus was recorded. Data for the four leaves were averaged for each branch. Data were subjected to analysis of variance (SPSS 9.0). If treatment differences were significant, differences between oil treatments and controls were further explored using Tukey’s HSD. Phytotoxic effects were determined by checking leaf drop, growth of sprouts, leaf border necrosis and leaf spots 15 days after the last treatment.
Results

*Phytotoxicity to raspberry*

There was not significant difference between treatments in the average number (p=0.658) and length (p=0.525) of sprouts although there was a linear decrease of shoot length ($R^2=0.88, 0.78$ and $0.70$ for plant, mineral and fish oils) with increasing oils concentrations (Figure 1). The number of leaves developed by plants sprayed with Codacide was significantly (p<0.05) smaller than controls and other oil treatments when applied at 2% (Figure 2). For that oil there is a linear decrease in number of leaves with oil concentration ($R^2=0.90$).

Figure 1. Effect of seven treatments with plant, mineral or fish oils at four concentrations on raspberry shoot length.

Figure 2. Effect of 7 treatments with plant, mineral or fish oils on number of leaves of raspberry plants.

There were not significant differences between treatments and controls in the plant general condition as established with the 1-5 scale ($F=0.628; p=0.536$) but control plants showed a much better general condition than oil treated plants; this is probably due to the heterogeneity of data with high standard deviations. Inside treatments there was a significant dosage effect which may be observed in graphs in Figure 3; for plant and fish oils, increasing concentrations produced a linear decrease of general condition of plants ($R^2=0.92$ and $0.74$ respectively); it was also evident looking at the plants, especially those sprayed with the 2% concentration which showed pale colour, were less vigorous or presented leaf drop or spots.
Control of powdery mildew and phytotoxicity to Blackcurrant

There were no significant differences between the effectiveness of oils when applied at 1 or 2% and therefore only 1% graphs are shown in Figure 4. The three oils were equally effective in controlling powdery mildew and differences respect to control were highly significant from the first recording date 15 days after the first treatment ($F=5.484; \ p=0.000$) and they kept through all summer until the last data uptake ($F=14.21; \ p=0.000$) on September 30th. The fungicide Sperosul showed lower effectiveness than oils but it could be due to rainfall few days after first and third sprays that was not strong enough to wash up the oils but could easily eliminate the colloid sulphur from the leaves surface.

The most common phytotoxic effect of oils was slight old leaf drop that happened in most plants. Some other symptoms seem to be characteristics of some oils: plants sprayed at both concentrations with Codacid showed, after the third treatment, necrotic spots in the oldest leaves; necrosis of leaf border happened mainly in plants sprayed with mineral oil but also in some of those sprayed with fish oil at 2%. Damages were not uniform and many times it was difficult to know exactly their origin due to interferences: powdery mildew damages in the water control and irrigation problems which stressed the plants irregularly and could be responsible of some of the symptoms. Most mentioned symptoms occurred only at the end of the summer, after the third treatment.
Discussion

The so-called "biocompatible" pesticides (Horst et al., 1992) are particularly interesting for the control of pests and diseases in berry crops. This study demonstrates that some mineral, plant and fish oils are effective in controlling powdery mildew in Blackcurrant. A mineral oil controlled effectively *Sphaerotheca mors-uvae* in Gooseberry (Barker and Lees, 1914, cited by Calpouzos, 1966) and most studies just mention mineral oils but in this preliminary assay the control of powdery mildew in blackberry using plant or fish oil was excellent. Mineral oils have been the most widely used because they are commercially available and registered for their use on many crops as insecticides or coadjuvants (Horst et al., 1992; Dell et al., 1998; Wicks et al., 1999; McGrath and Shishkoff, 2000) but plant oils with different origins (canola, soybean, sunflower, olive) are also tested because of their advantages as alimentary products although they need further research to obtain products with standard properties and homogeneous behaviour when used on plants. Fish oils have been assayed only in the control of insects (Beattie et al., 1999) but our results show that they are as effective as mineral or canola oils in the control of powdery mildew in blackcurrant as they were in grapevine powdery mildew (Silvarrey et al., 2000); as for plant oils, they need to be standardised to be used on crops and some other aspects as residual fruit stink should be investigated.

The phytotoxicity exhibited by the plant oils was expected, especially at concentrations over 1%. Raspberry seems to be more sensitive than grapevine (Silvarrey et al., 2000) but several factors could contribute to increased phytotoxicity in our test: raspberry sprouts were very young and had developed in glasshouse where no washing or degradation of oils occurs and too many and too frequent sprays were applied. Blackcurrant shrubs showed more characteristic symptoms but as mentioned previously the irrigation problems could contribute to stress the plants and the five treatments applied at high concentrations could be excessive. Taking into account that the first oil spray stopped the powdery mildew infection, one or two more would have probably prevent further infections during the summer without any phytotoxic effect. We have also to consider that the plant and fish oils were not formulated for the purpose we used them for in this study; furthermore, the Codaci de is manufactured and formulated for use as spray adjuvant together with herbicides. Products developed specifically for control of plant pests and diseases may not be phytotoxic at all and could play an important role in integrated pest management programs in berry crops.

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References


