Progress towards Integrated Crop Management (ICM) for European raspberry production

S.C. Gordon, J.A.T. Woodford, B. Williamson, A.N.E. Birch & A.T. Jones

Raspberries are an important, high-value, horticultural crop grown without subsidy in many northern European countries. There is also an increased production in more southern countries such as France, Greece, Italy, Portugal, Spain, and Switzerland. Total production in Europe in 1997 was estimated to be *c.*240,000 tonnes[1]. Whilst most raspberries are grown for the fresh market, a high proportion of the Eastern European, French and Scottish raspberry industries, is used for processing.

Arthropod pests and diseases of cane fruits may cause both direct and indirect damage and loss. At present, methods to protect crops against such effects rely largely on the application of broad-spectrum insecticides and fungicides. The number and spectrum of active ingredients in these products approved for use on cane fruit crops is declining rapidly across Europe, due to the high cost of registration for use in this minor crop. In the very near future, growers will need to find alternative methods to manage pests and diseases, using fewer applications of a very limited number of products. At the same time, consumers and processors are encouraging growers to continue to produce high quality fruit with the minimum amount of pesticides. These demands will inevitably lead to changes in crop management.

Direct damage to berry fruits through yield loss or fruit blemish caused by arthropods, includes that caused by raspberry beetle (*Byturus tomentosus*), clay-coloured weevil (*Otiorhynchus singularis*), raspberry moth (*Lampronia rubiella*) and two-spotted spider mite (*Tetranychus urticae*). Direct damage is also caused by grey mould fungus (*Botrytis cinerea*). Indirect damage by the aphids, *Amphorophora idaei* (*Am. idaei*) and *Aphis idaei* (*A. idaei*) and the leafhopper, *Macropsis fuscula*, is caused by the transmission of plant viruses and the phytoplasma agent of rubus stunt respectively (Table 1). Additionally, the wounding caused by the raspberry cane midge (*Resseliella theobaldi*) predisposes plants to fungal infection[2]. Furthermore, if insects are not adequately controlled on fruiting plants before and at harvest, the risk of contamination of the harvested fruit with these organisms is greatly increased. The most common arthropods causing rejection of fresh and processed fruit are aphids, earwigs, larvae of beneficial predators, and parasites.

Insecticide and fungicide usage in raspberry Contact organophosphorus-based pesticides account for about 70% of the insecticide and acaricide use in raspberry crops in the UK. They are used mainly to control raspberry beetle and raspberry cane midge. Systemic organophosphorus-based products, targeted primarily against aphids, currently account for less than 5% of insecticide usage and this is due to the widespread and increased cultivation of aphid-resistant raspberry cultivars. However, the need for aphicides may increase as the incidence of resistance-breaking raspberry aphid biotypes become more widespread. The use of acaricides is also declining as growers turn to biological control of two-spotted spider mite. Broad-spectrum fungicides, such as dichofluanid that is used widely during blossom to control grey mould, have additional benefits by controlling other fungal diseases, such as cane spot (*Elsinoe veneta*), spur blight (*Didymella applanata*) and stamen blight (*Hapalosphaeria deformans*). Although more target specific fungicides are available or being developed, their use may lead to damaging outbreaks of the fungi currently controlled by the broad-spectrum products. Changes in husbandry practice, such as protected cultivation or machine harvesting, have given rise to new problems and they will result in the on-going need for fungicides.

Monitoring, scouting and forecasting   Many of the components of an ICM programme for raspberries are in place but real progress will depend on their implementation at the farm level. This will inevitably place a greater management burden on fruit growers and technical support staff, as they will have to collect and assimilate more information on the health of the crop and make more decisions on its treatments. The information that they need to gather will be based on regular crop walks during daylight hours and after dark to check for pests and pathogens, the use of insect traps and the knowledge of control thresholds for spray strategies, and the use of models to predict the onset of pest and disease attack. Useful information about the health status of canes can be gained by routine sampling during winter of, for example, midge blight and cane spot.

The raspberry cane midge oviposition model is a good example of a system that successfully predicts the onset of insect attack in the spring. This permits growers to assess the risk of damage to their crop by assessing midge levels in the previous year and to decide, if and when, to apply insecticides to manage first generation midge numbers. Numbers of the raspberry beetle, the most important flower and fruit pest in northern Europe, can be assessed by examination of flower buds in the spring. Recently, white sticky traps (Rebell® bianco), developed in Switzerland, have been shown to trap adult raspberry beetles. They are currently being assessed to develop a spray threshold in various European countries, as part of the 'Reduced Application of Chemicals in European Raspberry production' (RACER) project (Fig. 1). Successful development of ICM will require a planned, multi-national approach, with transfer of existing research to new areas and its adaptation to the local environmental conditions. Although monitoring and forecasting pest and disease incidence is an important part of ICM systems, they still rely on having the chemicals or strategies to control the pest or pathogen. However, many of the former are under threat of being withdrawn from use. There is now an urgent need for the registration and release of newer, more environmentally benign, pesticides that are effective against common raspberry pests and diseases.

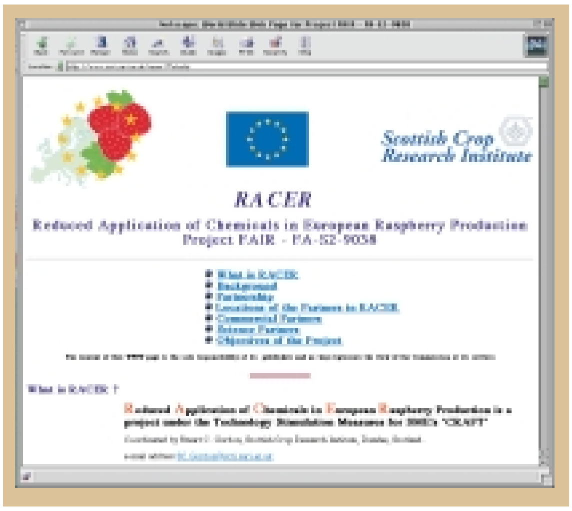

Figure 1 The RACER project was conceived by members of the European raspberry producers and processing industry to help them to produce high quality fruit in an environmentally acceptable manner, meeting the aspirations of the consumers, supermarkets and processors. http://www.scri.sari.ac.uk/Racer/

Plant resistance   Plant resistance, provided it is durable, remains one of the most efficient, benign and cost-effective means of pest and disease control. Several examples of such resistance occur in raspberry. One of the best documented and utilised is resistance to the large raspberry aphid, *Amphorophora idaei* (*Am. idaei*). The major importance of this aphid is as a vector of at least four different viruses of raspberry (Table 1). These viruses, either alone or in combination, cause serious losses in plant growth and vigour, and

	Common name†	Latin Name	Type of Damage	Distribution in Europe	Importance
Pests	Large Raspberry Aphid	*Amphorophora idaei*	Virus Vector/Foliage	Widespread/Northern	*****
	Small Raspberry Aphid	*Aphis idaei*	Virus Vector/Foliage	Widespread/Southern	**
	Rubus leafhoppers	*Macropsis* spp.	MLO Vector	Localised	*
	Common Green Capsid	*Lygocoris pabulinus*	Foliage	Localised	*
	European Tarnished Bug	*Lygus rugulipennis*	Foliage/Flowers	Widespread/Northern	*
	Raspberry Beetle	*Byturus tomentosus*	Flowers/Fruit/Contaminant	Widespread/Throughout	*****
	Clay-coloured Weevil	*Otiorhynchus singularis*	Buds/Foliage	Localised/Northern	***
	Strawberry Blossom Weevil	*Anthonomus rubi*	Buds/Flowers	Localised/Southern	**
	Raspberry Cane Midge	*Resseliella theobaldi*	Canes (Midge Blight)	Widespread/Throughout	*****
	Raspberry Moth	*Lampronia rubiella*	Buds	Localised/Northern	***
	Double Dart Moth	*Graphiphora augur*	Buds	Localised/Scotland	***
	Two-Spotted Spider Mite	*Tetranychus urticae*	Foliage	Widespread	****
	Raspberry Leaf and Bud Mite	*Phyllocoptes gracilis*	Foliage	Widespread but sporadic	***
Diseases	*Fungal diseases*				
	Grey Mould	*Botrytis cinerea*	Canes/Fruit	Widespread	*****
	Cane Blight	*Leptosphaeria coniothyrium*	Canes	Widespread	***
	Midge Blight (Disease complex)	*R. theobaldi + Phoma/Fusarium*	Canes	Widespread	*****
	Cane Spot	*Elsinoe veneta*	Canes/Leaves/Fruit	Widespread	**
	Raspberry yellow rust	*Phragmidium rubi-idaei*	Leaves	Widespread	**
	Root-rot	*Phytophthora fragariae* var *rubi*	Roots	Widespread	*****
	Am. idaei-borne viruses				
	Symptomless decline	*Black raspberry necrosis virus*	Latent	Widespread?	*
	Leaf spot mosaic/decline	*Raspberry leaf mottle virus*	Foliage/Vigour	Widespread?	*****
	Leaf spot mosaic/decline	*Raspberry leaf spot virus*	Foliage/Vigour	Widespread?	*****
	Yellow mosaic	*Rubus yellow net virus* (RYNV)	Foliage	Widespread?	*
	Veinbanding mosaic/decline	RYNV + other viruses	Foliage/Vigour	Widespread?	****
	Aphis ideai-bourne viruses				
	Vein chlorosis	*Raspberry vein chlorosis virus*	Foliage	Widespread	**
	Pollen-borne virus				
	Bushy dwarf/Yellows	*Raspberry bushy dwarf virus*	Foliage/Fruit	Widespread	**?
	Nematode-borne				
	Yellow dwarf/decline	*Arabis mosaic virus*	Foliage/Vigour	Localised/ Northern	***
	Scottish leaf curl/decline	*Raspberry ringspot virus*	Foliage/Vigour	Localised/ Northern	***
	Decline	*Strawberry latent ringspot virus*	Foliage/Vigour	Localised/ Northern	**
	Ringspot/decline	*Tomato black ring virus*	Foliage/Vigour	Localised/ Northern	***
	Leafhopper-borne agent				
	Rubus stunt	Phytoplasma	Foliage/flowers	Continental Europe	***

MLO = Mycoplasma like organism.
† Common name in the UK, may vary elsewhere in Europe

***** = Of major importance, causing severe loss/damage if not controlled;
**** = Important, severe loss/damage;
*** = Locally important causing moderate/severe damage;
** = Locally important causing slight/moderate damage;
* = Minor, cosmetic damage

Table 1 Major pests and diseases of raspberry in Europe: their damage, distribution and importance.

fruit yield and quality[3]. Gene A_1 and uncharacterised minor genes from red raspberry confer effective resistance to some common biotypes of this aphid, and gene A_{10} from American black raspberry (*R. occidentalis*) is effective against all described biotypes. Over the last 20 years in Britain, control of this aphid vector by these resistance genes has also given very effective control of the four viruses it transmits, without the need for aphicides[3]. However, very recently, *Am. idaei* has been found colonising gene A_{10}-containing cultivars in Britain, suggesting that new A_{10}-breaking biotypes of this aphid have developed. No immunity or resistance has been found in *Rubus* germplasm to any of the four viruses transmitted by *Am. idaei*, so that the control of the spread and effects of these viruses continues to depend on effective control of this aphid vector. In the absence of resistance genes against the new *Am. idaei* biotypes, alternative control strategies for this common aphid need to be devised urgently.

The small raspberry aphid, *A. idaei*, common on raspberry throughout continental Europe, seems to have increased in incidence in more northern latitudes. It is generally regarded as of low significance as a pest and derives its importance only as the known vector of raspberry vein chlorosis virus (RVCV). This virus, that affects plant growth and fruit quality, has increased in incidence in crops in recent years. No sources of resistance to *A. idaei* have been identified in raspberry but immunity to RVCV in some North American *R. idaeus* var. *strigosus* cultivars has been identified. Work at SCRI has shown that immunity or very strong resistance to RVCV can be introduced fairly readily into raspberry from these sources of immunity[4], offering an effective means of controlling this virus.

The pollen-borne, raspberry bushy dwarf virus (RBDV) is common in raspberry world-wide. In sensitive cultivars it causes yellows disease and/or crumbly fruit that greatly affects fruit quality[5]. In combination with aphid-borne viruses, it can cause greatly decreased vigour and productivity (bushy dwarf disease). A single dominant gene *Bu*, present in several cultivars, provides immunity to common (S) strains of RBDV, and this gene has been effective against RBDV infection in the field world-wide for more than 50 years. However, the virus is increasing in prevalence in many countries due to the increased planting of cultivars lacking this gene and, in some localities, to the occurrence of strains of this virus, termed resistance-breaking (RB), that can infect cultivars immune to S strains. The occurrence of such RB strains is of serious concern because plant resistance is the only means of controlling this virus in crops. Because of this impasse to the control of RB strains, work is underway at SCRI to produce, evaluate and assess the risks of transgenic resistance to RBDV, using various constructs of different regions of the viral genome.

Currently, control of the four nematode-borne viruses that affect raspberry in Europe, depends on the use of soil fumigants to kill the nematode vectors and the application of herbicides to remove virus sources. Whilst this has been very effective for viruses transmitted by *Longidorus* nematodes (raspberry ringspot and tomato black ring), it has been much less so for those viruses transmitted by *Xiphinema* nematodes (arabis mosaic and strawberry latent ringspot). This is because vectors retain the latter viruses for very long periods. Genes for immunity to one or more of the four viruses have been identified in raspberry but they are not effective against all strains of the viruses involved, making their deployment of little value commercially. With the impending withdrawal of some widely used soil fumigants from commerce, alternative control strategies for these viruses are required. One possibility being explored by SCRI is the use of virus sequences as transgenes in raspberry and preliminary experiments in a *Nicotiana* model have shown the efficacy of this approach. It remains to be seen if this approach is effective in raspberry and what risks may be associated with its use.

References

[1] FAO (1998). *FAO Production Yearbook 1997* 51, 171.

[2] Gordon, S.C., Woodford, J.A.T. & Birch, A.N.E. (1997). *Journal of Horticultural Science* 72, 831-862.

[3] Jones A.T. (1986). *Crop Research* 26, 127-171.

[4] Jennings D.L. & Jones A.T. (1986). *Annals of Applied Biology* 108, 417-422.

[5] Jones A.T. *et al.* (1982). *Annals of Applied Biology* 100, 135-147.