SESSION 6C

INTEGRATED CROP MANAGEMENT IN FIELD VEGETABLES

Chairman & Session Organiser:	N Caspell *ADAS Boxworth, Cambridge, UK*
Papers:	6C-1 to 6C-4

What impact is ICM having on pest and disease management in field vegetables?

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ABSTRACT

The introduction of Integrated Crop Management (ICM) via assured produce protocols into field vegetable production in the UK has been an evolutionary process, and over a period of years has had a profound effect on growers and ancillary industries. These include structural effects on growers businesses, the wider introduction of pest and disease monitoring and forecasting systems, product selection difficulties for pesticide manufacturers, and changing relationships between agrochemical distributors and their grower clients. A number of tensions have also become apparent, including the need to reconcile demands for damage, blemish and contaminant-free produce with a balanced approach to pesticide use demanded by ICM. New pest and disease management solutions are required to meet these evolving market demands. Mechanisms to measure the true impact of ICM are also required, and these require intelligence gathering and research to develop and implement.

INTRODUCTION

Producers of vegetables ultimately sold via retailers to UK consumers are now subject to increasing pressure to grow crops to accredited good horticultural practice standards. Embodied in this is the concept of Integrated Crop Management (ICM), which requires crops to be produced in an environmentally acceptable way, while still recognizing the grower's need for an economic return. The implementation and accreditation of these standards has developed into a complex infrastructure over the last five years in response to a perceived need to demonstrate to consumers that their food is being produced in a safe and environmentally benign way – in effect to offer consumers reassurance that food safety 'scares' should become a thing of the past.

Within the context of field vegetable production, ICM is now advocated in a widening range of product assurance schemes that present consumers with a potentially baffling array of labels and logos at the point of sale. In the UK, such schemes include the retailer-driven Tesco's Nature's Choice, and producer and/or retailer initiatives such as the Assured Produce Scheme (APS) and the British Farm Standard (branded by the Little Red Tractor logo, itself accredited by the Assured Produce Scheme). One or more of these schemes now covers approximately 70% of fresh produce producers in the UK. It could even be argued that organic farming standards are a form of produce assurance scheme. In recognition of the fact that many fresh and processed vegetables sold in the UK, particularly between October and March, are sourced from southern Europe, pan-European assured produce standards have also now been introduced under the auspices of EUREP-GAP (Garbutt, 2000). Even retailer-led food-orientated assurance schemes such as the Global Food Safety Initiative (launched in 2000) include statements drawing attention to the need for pest and disease management to adhere to

ICM principles. Despite this plethora of schemes, there is reasonable compatibility between them in terms of their scope, which saves growers substantial time and costs in not having to meet many potentially different requirements for each of their market outlets.

The introduction of this complexity of assurance schemes, all of them espousing ICM, cannot have occurred without considerable knock-on effects amongst growers and ancillary industries, and is probably a tacit recognition that vegetable producers in the UK (and Europe) needed to adapt their production systems to become consistent with the principles of ICM. This paper examines what some of these changes have been with particular reference to pest and disease management in vegetables, and highlights some of the tensions and dichotomies that have been created. Within the context of this conference, a particularly crucial issue is whether the introduction of ICM has in fact resulted in a *measurable* shift in crop protection practices in vegetable production. The value of ICM cannot be determined without benchmarks against which to assess its economic and ecological merits (McRoberts *et al.*, 1998, but so far no attempt has been made to establish the necessary baseline data.

WHAT IS ICM?

The introduction of ICM principles in assured produce has begged the question of how ICM should actually be defined. As a concept in the UK, it arose out of work done within arable systems in the early to mid-1990s (e.g. the LIFE, IFS, TALISMAN and SCARAB projects), which examined whether production practices could modified to allow reductions in major inputs (particularly fertilisers and pesticides, e.g. Young *et al.*, 2001) as well as changes in crop and variety selection to suit more environmentally-desirable soil and field margin management practices. A key driver was whether such changes could be made while maintaining profitability. Today, probably the most widely accepted definition of ICM in the UK is that used by the LEAF (Linking the Environment and Farming) scheme, which states that 'ICM is a whole-farm policy aiming to provide the basis for efficient and profitable production which is economically viable and environmentally responsible (Drummond & Purslow, 1997). Within the Assured Produce Scheme, ICM is similarly defined as 'good horticultural practices with emphasis on reducing whenever possible the use of pesticides, optimum use of fertilisers and improved protection of the environment'.

The process of making all sectors of the agricultural and horticultural industry aware of what ICM is and how to implement it has not been straightforward. In 1996, a survey of growers' awareness of ICM (Bradshaw *et al.*, 1996) indicated a relatively poor understanding of what ICM and Integrated Pest Management (IPM) were. Amongst field vegetable growers, 59% of respondents indicated that they either had only a rough idea of what ICM was, or were confused by the term. Only 12% claimed to fully understand ICM. No recent comparable survey data are available, but it would be reasonable to assume that the situation in 2002 is substantially different. It is clear that the definition, introduction and understanding of ICM over the last five years have been a continually evolving process. In fact, assured produce systems are now directly shaping what is meant by ICM by in effect using their regularly updated protocols as technology transfer vehicles to bring the results of relevant research into commercial practice.

STRUCTURAL EFFECTS

As the introduction of ICM via assured produce schemes has followed its evolutionary path, one of the consequences has been a forced change in attitudes not just amongst growers, but in the pesticide manufacturing and supply industries as well. Pesticide manufacturers now have to have an empathetic approach to consumer concerns about the food chain (Mitton, 2000), which of course include pesticide residues. Manufacturers have also had to recognise that the introduction of crop assurance protocols has meant that national or EU pesticide regulatory authorities are in effect no longer the final arbiters of what products are available for use on vegetable crops. Although pesticide registration procedures still govern what products are Approved, crop assurance protocols can effectively prevent the use of certain Approved products by proscribing the use of those products perceived to be 'environmentally undesirable'. This has forced some companies to defend their product positions by producing environmental information sheets containing data over and above that required on current label texts (Mitton, 2000).

There has also been a strong trend in the last five years for vegetable growers to employ highly qualified technical staff to enable them to cope with the specialist challenges posed by the introduction of assured produce schemes, as well as the other changes such as the introduction of maximum residue limits (MRLs). This has in turn resulted in a changing relationship between growers, agrochemical distributors (traditionally a prime source of technical advice), and manufacturers to one of partnership rather than a more prescriptive blueprint approach (Wallwork, 2000).

Structural changes in the agrochemical market have also been forced though by ICM–related issues, for example the grower-led initiative to stop the use of organophosphorus (OP) insecticides on carrots in the UK in the latter half of the 1990s which at least in part contributed to the demise of active ingredients such as triazophos, phorate and chlorfenvinphos in the UK. Although the concerns that drove this change were consumer concerns about pesticide residues, ironically the outcome has been an increase in the use of pyrethroid insecticides, themselves broad-spectrum products with arguably undesirable side-effects on beneficial insects.

EFFECTS ON PEST & DISEASE MANAGEMENT PRACTICES

General approaches

The standards of pest and disease management employed by field vegetable growers are generally high and will continue to improve as growers strive to achieve and maintain the necessary competencies required for the effective operation of an ICM programme within the context of assured produce systems. While ICM does require higher management standards than a purely prophylactic approach, it also poses a higher degree of risk to the grower who has, under ICM, to apply insecticides and fungicides only in response to a defined need. This is conceptualised in Figure 1, which indicates that as growers move more towards a more managed (ICM) approach to preventing pest and disease damage to their crops, they move closer to the 'control failure precipice'. This is the point at which the grower loses control over an ICM/IPM approach to controlling pest and disease attack, and the resulting crop damage renders the crop unsaleable and therefore worthless. As going over the 'control failure precipice' could spell financial disaster to a grower, one of the possible criticisms of the way ICM has been implemented on farms is that growers simply use some of the techniques of ICM, such as the use of trapping or monitoring systems, as a way of justifying what essentially remains a insecticide/fungicide prophylactic approach to pest and disease management. An example is the placing of a limited number of traps (e.g. sticky traps) in a very large field, and claiming that a few pest insects caught on the trap (possibly in conjunction with some relatively cursory crop inspections) justifies treatment of the whole field. This is clearly a rather crude interpretation of the principles of ICM, but allows the grower to 'tick the boxes' when it comes to an assured produce audit. However, despite the possible criticisms of the way they are used, there is no doubt that there is now far greater adoption of pest and disease monitoring systems and models, and this trend is set to continue provided the monitoring/modelling tools actually provide realistic and usable results.

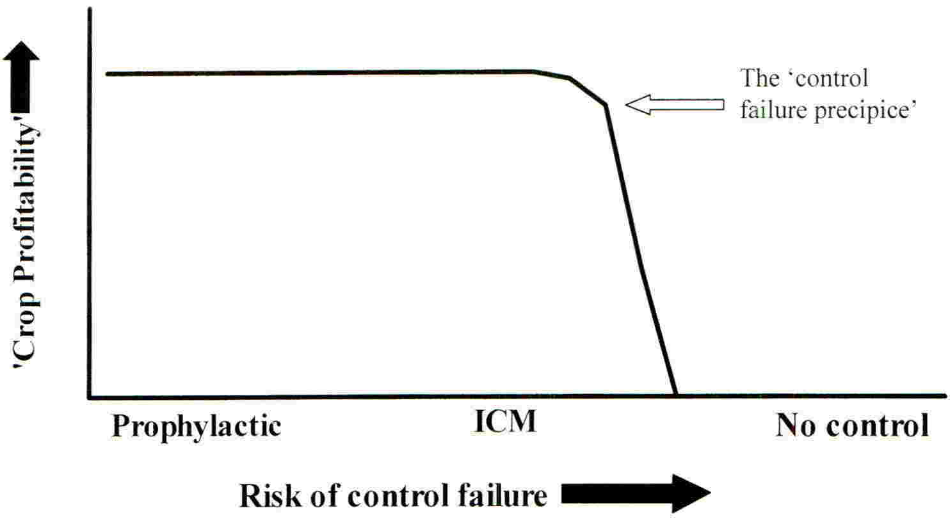

Figure 1. Conceptual representation of the impact on the risk of crop loss through pest and disease damage of moving from a prophylactic control approach to an ICM-based approach.

Zero tolerance in whole-head produce

One of the most serious issues facing field vegetable producers operating under an ICM regime is the extent to which the ICM system can 'guarantee' that produce will conform to the concept of 'zero tolerance' required by most retailers. This states that produce must be completely free of defects caused by pest or disease damage, or from the actual presence of dead of live insects or parts of them. This raises two important questions. Firstly, is the level of pesticide input required to achieve 'zero tolerance' actually too intensive to be justifiably termed ICM; and secondly, how should 'zero tolerance' be defined? The first question requires a philosophical answer, but the second can be dealt with by direct examination of produce. Packhouse quality control (QC) systems are designed to ensure that produce going into the supply chain meets the quality requirements of the customer. Yet the sheer volume of produce passing through packhouses in relation to the amount of produce sampled for QC purposes means that a realistic assessment of pest and disease damage levels is virtually never achieved. Recent work where large batches of different brassica crop types taken from packhouse lines were intensively examined to determine the 'true' pest infestation levels of apparently 'clean' produce (Figure 2) suggests that so-called zero tolerance does in fact mean a relatively high tolerance of pest incidence in some instances.

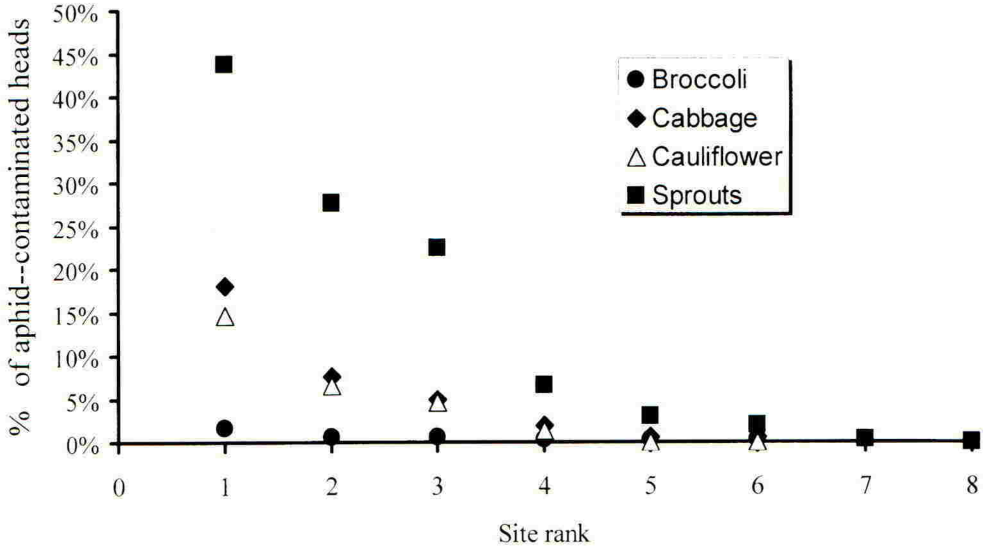

Figure 2. Percentage of brassica heads with live aphids sampled from packhouse lines in 2001 (n=6 for cabbage & cauliflower; n=8 for broccoli & sprouts). Sites ranked in descending order by infestation level for each crop type.

These data suggest that in the cleanest crops, zero tolerance is likely to equate to an aphid infestation level (data for other insects and pest damage are not shown) of zero to 5% of saleable crop units infested. Certain crop types (e.g. Brussels sprouts) are more prone to infestation than others (e.g. broccoli), but in the most extreme examples, aphid infestation levels of 15-45% were found – regardless of any other pest or disease presence/damage. The clear implication is that in the majority of cases, zero tolerance as perceived by the customer is in fact a level of infestation which is too low for routine packhouse QC inspections to detect reliably. Site and seasonal effects undoubtedly account for some of the variation in infestation levels. However, more structured studies of the degree to which the intensity and, critically, timing of pesticide application is related to final pest and disease infestation levels will help shape the direction and measurement of ICM in the future.

Contamination in processed salads

One of the most dramatic changes in the fresh produce market over the last five years has been the rapid rise in the popularity of bagged, ready-to-eat, mixed-leaf salad packs, as well as a whole range of other salad-containing ready-meal products.

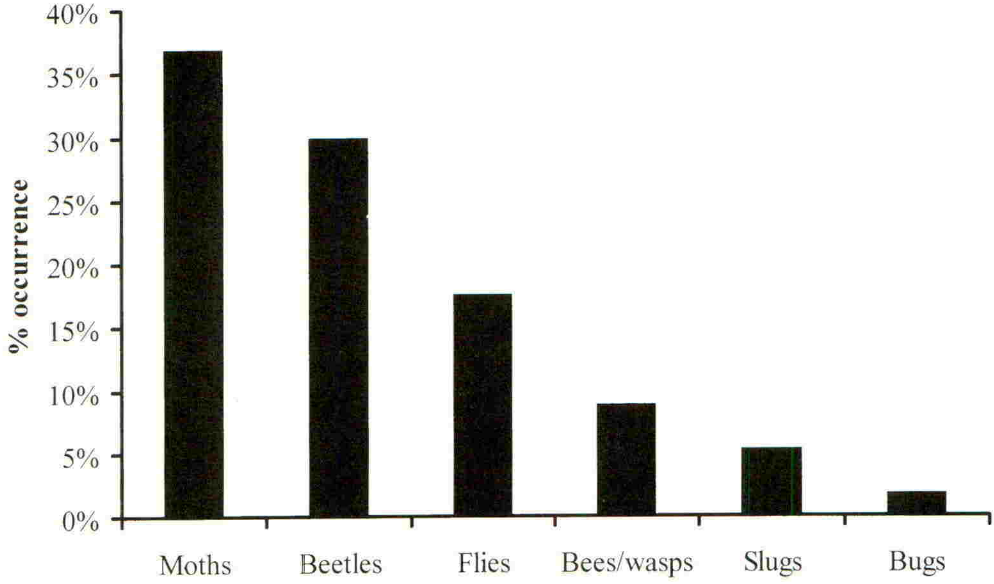

Figure 3. The incidence of different invertebrate groups identified as 'contaminants in salad packs (data ex ADAS Plant Clinic from samples received from various commercial sources).

The fact that consumers do not have to wash leaves from salad packs prior to eating them has meant that pack contaminants, including invertebrates, have become a significant issue for the processing industry. Complaints rates in the order of 5 per 100,000 packs (i.e. <0.0001% of units sold) are considered by some supermarkets to be excessive. This presents a unique challenge to growers supplying the raw salad material to ICM standards, as it has become clear that the invertebrates causing contamination come from a wide range of insect and other invertebrate groups (Figure 3). These mainly originate from the crop rather than the packhouse. Moreover, most of these contaminants are not 'traditional' pests, but are simply 'vagrant' invertebrates or beneficial insects present in the field environment, which would otherwise present no risk of crop loss to the grower. The fact that these have to be controlled to enable growers to ensure that contamination is minimised creates a major tension for the implementation of true ICM. On the one hand ICM protocols, with the support of retailers, are asking for improvements to the farm environment to ensure diversity of flora and fauna. On the other hand, those same retailers are demanding produce standards arguably impossible to achieve consistently without intensive pesticide input, including in some instances applications which may be targeted at controlling beneficial insects – hardly in the spirit of ICM. There is as yet no direct evidence that the introduction of ICM has resulted in decreased levels of crop pest or vagrant insect control leading to greater contamination of salads in the field. However, the necessary work to substantiate this has not been done, and a strategic research effort to identify best practice for contaminant management fully consistent with the principles of ICM is required.

Has pesticide use been influenced by ICM?

One of the most obvious potential measures of the impact of ICM on pest and disease management in field vegetables is the degree to which patterns of pesticide use have changed over the last five to seven years. Data from official pesticide usage surveys are available, but to be meaningful, any analysis of changes in pesticide use needs to be allied to reliable, concurrent data on actual pest and disease pressure on the crops in question. These latter data can only be obtained through structured crop surveys or other extensive data sets, and these are not currently done for vegetable crops in the UK. However, such an analysis has been done for insecticide use against aphids on potato, and although the full details cannot be described here, clear trends in pesticide use related to aphid infestation pressure were identified. Figure 4 shows the area of potatoes treated with different groups of insecticides in the period 1994-2000 (pesticide usage data is only available for every other year). In years when aphid pressure was high (1994 and 1996), the area treated was higher than in 1998 and 2000 when aphid pressure was much lower, a pattern which would be consistent with growers responding to actual infestation levels as ICM requires. However, it was clear that an element of routine treatment was still used by some growers. The situation on field vegetables is probably broadly similar.

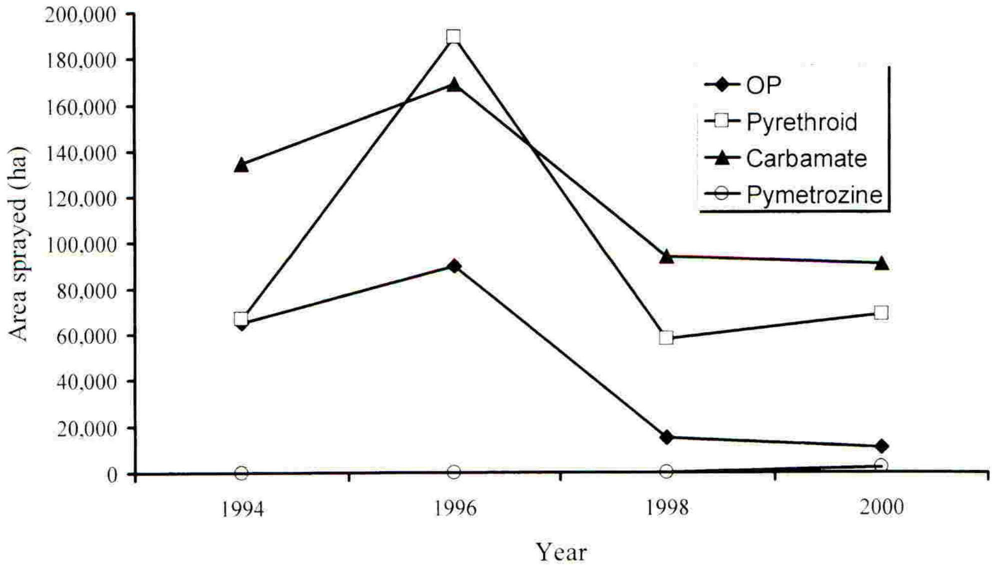

Figure 4. Changes in the type and amount of insecticides used on potato crops in the period 1994-2000.

The data also show a clear move away from organophosphorus (OP) insecticide usage (in part due to product withdrawals), and the initial appearance of a new insecticide (pymetrozine) on the market. Whether such structural changes in the market would have occurred even without the introduction of ICM is an open question.

Until the last couple of years, neither limited insecticide product choice or insecticide resistance has seriously limited the ability of growers to achieve good pest and disease management on field vegetables. However, this situation will change. 'Minor use' products will be lost as a result of on-going pesticide reviews, and this is already leaving significant problems for pest management in some crops, e.g. cabbage root fly (*Delia radicum*) on swede in the UK. New insecticide resistance problems are also emerging relating to the control of important vegetable pests, including peach-potato aphid (*Myzus persicae*), potato aphid (*Macrosiphum euphorbiae*) and currant-lettuce aphid (*Nasonovia ribisnigri*). Growers must keep abreast of all these developments and seek solutions consistent with the principles of ICM.

CONCLUSIONS

The introduction of ICM into field vegetable production has been an evolutionary process, and over a period of years has had a profound effect on growers and ancillary industries. There is a need to reconcile demands for damage, blemish and contaminant-free produce with a balanced approach to pesticide use demanded by ICM. New pest and disease management solutions are required to meet evolving market demands. Mechanisms to measure the true impact of ICM are also required, and these require intelligence gathering and research to develop and implement.

ACKNOWLEDGEMENTS

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REFERENCES

Bradshaw N J ; Parham C J; Croxford A C (1996). The awareness, use and promotion of integrated control techniques on pests, diseases and weeds in British agriculture and horticulture. *Proceedings of the Brighton Conference – Pests & Diseases*, **2**, 591-596.

Drummond, C J; Purslow, J (1997). Adopting integrated pest management – a practical whole-farm approach for the optimisation of agrochemical use. *Proceedings of the Brighton Conference – Weeds*, **2**, 461-468.

Garbutt N (2000). Meeting consumer demands for food safety: European retailer protocols for crop protection programmes. *Proceedings of the BCPC Conference – Pests & Diseases*, **1**, 129-132.

Hewson R T; Sagenmüller A; Scholz-Tonga E M; Fabretti JP; Lobo D A G; de Saint Blanquat A; Schreuder R (1998). Global integrated crop management success stories. *Proceedings of the Brighton Conference – Pests & Diseases*, **1**, 161-168.

McRoberts N; Edwards-Jones G; Sutherland A; Chadwick L (1998). Methods for evaluating farm practices and attitudes to integrated crop management systems. *Proceedings of the Brighton Conference – Pests & Diseases*, **1**, 155-160.

Mitton, P J (2000). The implications of food assurance schemes for the pesticide manufacturer. *Proceedings of the BCPC Conference – Pests & Diseases*, **1**, 143-148.

Wallwork C (2000). Working within food assurance protocols; current farm practice in the UK. *Proceedings of the BCPC Conference – Pests & Diseases*, **1**, 139-142.

Young J E B; Griffin M J; Alford D V; Ogilvy S E (eds) (2001). *The TALISMAN and SCARAB projects*. London: DEFRA 415 pp.

Crop protection in integrated production of field vegetables in Sweden - the status of IPM

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ABSTRACT

The Integrated Production (IP) of field vegetable crops was started in Sweden in 1992 by the growers' organisation. 60% of the vegetable acreage is included in the IP-project that encourages an ecologically and economically sound growing system. The IP-rules, that have to be followed on the entire farm, state that crop protection should be based on preventative and cultural methods. Biological control should be given priority and the use of pesticides minimised. Monitoring of pests, diseases and weeds must be done regularly. Food safety has priority and the growers' working environment should be improved. Education, documentation and control are mandatory. The IP concept is well in line with the official Swedish policy to develop a sustainable agriculture. Programmes for pesticide risk reduction and pesticide use reduction have run since 1985. The difference between IP and conventionally produced vegetables in Sweden is, as regards crop protection, relatively small. This can be explained by the continuous tightening of laws and legal restrictions which are mandatory for all growers, and the lack of sufficient Integrated Pest Management (IPM) tools. Documentation and traceability give added value to the IP produce.

INTRODUCTION

The consumers' care for the environment and awareness of the hazards posed by pesticides have influenced the production process and the market for fruit and vegetables in Sweden. As well as a demand for products from organic farming, products from integrated production continously increase. The growers' organisation (GRO) has organised Integrated Production (IP) since 1992, a project that now includes around 60% of field vegetable production. Retailers support the IP concept and for some supermarkets extended protocols are required. IP stands for an ecologically and economically sound growing system in which crop protection is based on Integrated Pest Management (IPM).

Vegetables produced for the fresh-market, as well as for processing, have to be of high quality and meet the EU standards. With respect to crop protection, it is stated that "damage by pests and diseases, contamination of the produce by insects, is not permitted" (Anonymous, 1995). Crop protection has therefore a central role where the use of pesticides is restricted by laws and regulations to secure food safety, the environment and workers' health.

There is no official definition of IP or IPM in Sweden, but as a Member State of the EU, Sweden has to follow the Council Directive 91/414/EEC where it is stated that the principles of integrated control shall be applied whenever possible. "Integrated control" is defined as "the rational application of a combination of biological, biotechnological, chemical, cultural or plant-breeding measures whereby the use of chemical plant protection products is limited to the strict minimum necessary to maintain the pest population at levels below those causing economically unacceptable damage or loss".

This paper will describe the development of the Integrated Production concept for field vegetables for the fresh market in Sweden and focus on crop protection. Examples of interactions with other IP/IPM promoting programmes are given and the status of IPM is discussed.

FIELD VEGETABLE PRODUCTION IN SWEDEN

Swedish field vegetables are grown on 6,150 ha by 1,150 growers. Over the last 10 years a slight increase in total area has been noted while the number of growers has decreased by over 30%. The trend is towards fewer, larger and more specialized farms. Organic production represents around 10% of the vegetable acreage and nearly 60% is produced according to the IP concept. In addition to these vegetables, produced mainly for the fresh market, 9,000 ha of peas are grown for the freezing and canning industry. The production of vegetables for processing follows the rules set by the industry which are in line with the IP concept. Swedish vegetable growers are successful in competing in quality and price compared to other countries. The self-sufficiency level of 93% of carrots, 64 % of onion and leek, 40% of lettuce and 43 % of brassica vegetables illustrates this. Most importing of vegetables takes place during the winter months. Exporting is restricted to frozen peas, comprising around 60% of the harvest.

THE IP-PROJECT INITIATED BY THE GROWERS

Organisation

Integrated Production of field vegetable crops was started as a project in Sweden in 1992 by the growers' organisation. In agreement with the fruit growers, who had been the IP pioneers in Sweden in the 80's, Integrated Production was defined as a farming system in which

- ecologically safe production methods have priority,
- the use of pesticides and fertilisers are minimised,
- food safety has priority,
- the grower's working environment is improved,
- the production process is documented and controlled.

The IP project was considered to be of crucial importance to the future of Swedish vegetable production, as it was expected that products from integrated production from other European countries would soon be imported. Both general guidelines and crop specific recommendations were produced. The aim was to make the overall recommendations attainable by as many growers as possible. It was stressed, however, that integrated production is a dynamic process in which the rules and recommendations are being tightened gradually towards environmentally safer methods.

Since 1998 the different IP programmes, which had been developed for fresh market production (vegetables, fruit, berries and table potatoes), were co-ordinated under "Green Production Ltd". The different IP guidelines were combined in one document, "Rules for Integrated Production" (www.gronproduktion.se). These rules must be followed on the entire farm. The continuous education of growers and operating managers is stressed. Growers are certified as IP growers once they have followed the appropriate course of education, and provided they agree to follow the guidelines and recommendations, document all steps in their production practices and submit their documentation to inspection whenever required. Production has been controlled by the independent organisation SMAK (Swedish Tablepotato Control Agency Ltd) since 1995. About 60% of the acreage of vegetables for the fresh market has been grown using the Integrated Production approach since 1996. The main reason for the high uptake by the growers is due, frankly, to the demands of the market. The biggest buyers, led by the main supermarket chains ICA and KF, announced that they would only buy vegetables from growers who are certified IP producers.

The requirements for environmental care and workers safety, as stated by Swedish laws and regulations, are the basis of the IP program. Additional rules and recommendations are presented for

- nutrient management and irrigation, for reducing losses of nutrients to air and water,
- crop protection (see below),
- energy use, for safe handling and the use of "green" fuel,
- post harvest handling, for traceability and the guarantee of high hygienic standard during storing and packaging,
- workers' protection.

Crop protection in IP

It is stated in the "Rules for Integrated Production" that for the control of pests, diseases and weeds, preventative and cultural methods as well as biological control should be given priority. The use of chemicals should be minimised and monitoring of pests, diseases and weeds must be done regularly. Rules and recommendations, in addition to Swedish laws and regulations, are given and include:

Preventative measures

- Favourable growing sites and good soils should be selected.
- A 4-year crop rotation is recommended as a minimum to avoid increasing the pressure from pests and diseases.
- Priority should be given to cultivars with resistance to diseases and pests.
- Seeds and seedlings should be healthy and of high quality.

Direct control measures

- Warning/forecasting methods for pests and diseases must be used if available.
- Field inspections and documentation of the occurrence of weeds, pests and diseases as well as the developmental stage of the crop must be done regularly so as to justify any plant protection measure.

- The plant protection product must be registered for the intended use. When selecting a pesticide any side effects on beneficial fauna, micro-organisms and pollinating insects must be considered.
- Band spraying of pesticides is recommended.

Pesticide risk reduction measures

- Treatments with pesticides in the autumn should be avoided in hilly terrain near water.
- When filling and cleaning the sprayer recommendations are given as to how the farmer should fulfil legal requirements.
- A functional test of the sprayer must be carried out every second year.

THE APPROACH TO IPM BY THE SWEDISH GOVERNMENT

The official Swedish policy is to develop a sustainable agriculture which is safe for the environment and human health, and with the goal that organic farming shall reach 20% in the year 2005. Four out of of 15 national goals for environmental quality, "good quality ground-water", "flourishing lakes and streams", "varied agricultural landscape" and "a non-toxic environment" have direct impact on crop protection work and especially the use of pesticides.

Integrated Pest Management (IPM) is not specified by Swedish authorities; instead the use of plant protection products has been targeted. Programmes for pesticide risk reduction and pesticide use reduction have been run since 1985. The National Chemicals Inspectorate, the Swedish Board of Agriculture, the National Food Administration, the National Board of Occupational Safety and Health and the Swedish Environmental Protection Agency have developed these programmes. These Swedish national programmes for the reduction of pesticide use and risks to health and environment run over 5 year periods:

- 1986-1990 Goal: 50% reduction of pesticide use and risks.
- 1991-1996 Goal: Further 50% reduction of pesticide use and risks.
- 1996-2001 Maintain achieved levels of pesticide use. Aim at a further reduction of risks.
- 2001-2006 Minimise risks to health and environment.

The Swedish Board of Agriculture has administered the program for pesticide use reduction. The support given to the advisory services was strengthened and emphasis was put on warning/forecasting systems for pests and diseases and supervised control. Applied research in this field was funded. The goal of the first programme was fulfilled by a 50% reduction of pesticide use by volume up until 1990. A further 30% reduction was reached by 1996 (SJV, 1998). No further reduction in use by volume has been noted since 1996. In the recent programme the objective is to reduce the risks of pesticides for the environment, workers and consumers. Pesticide use reduction is encouraged (SJV, 2002).

With a focus on risk reduction all pesticides were re-registered in 1990-1995 by the National Chemical Inspectorate. Cut-off criteria (i.e. criteria for banning) were established to identify pesticides with unwanted properties based on health and on environmental hazards (Andersson *et al.*, 1992). In the first round, 20 formerly registered pesticides were removed from the market and seven more were severely restricted in their use. Pesticides must then be re-registered every five years. Several pesticides of crucial importance for vegetable growers have been withdrawn or restricted based on unacceptable properties or insufficient documentation. Now Sweden, together with Finland and Denmark has the lowest number of registered pesticides (active substances) compared with other Member States in EU (Figure 1). The Swedish authorities hope that the policy in the growers' run IP projects will have the result that substances once rejected in the re-registration phase will not find their way to the market again, even if they enter the positive list of approved substances (Annex I) in Directive 91/414/EEC.

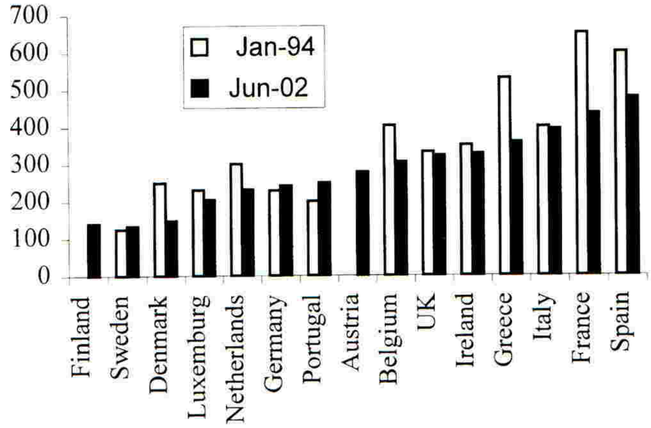

Figure 1. Number of registered plant protection products (active substances on July 25th, 1993) in the EU Member States (EU, 2002).

To secure the safe handling of pesticides and to reduce risks to the environment and human health Sweden has laws and regulations regarding spraying, transport and storing of pesticides. The person who is spraying must have a valid licence. Safety precautions during spraying are required and buffer zones, temperature, wind speed and wind direction etc must be respected and documented. Filling and cleaning the sprayer must be done so as to avoid spillage and pollution of the environment.

THE INTERACTION BETWEEN THE IP AND IPM APPROACH IN OTHER PROGRAMMES

Safe Pesticide Use

The Swedish policy for reducing pesticide risks to the environment and human health has been adopted by the Federation of Swedish Farmers who initiated the campaign called "Safe Pesticide Use". Information and education are targeted at farmers, sales people and others who are dealing with pesticides (www.lrf.se/sv/). IP vegetable growers have to participate in these training courses.

"Odling i Balans"

"Odling i Balans" is a Swedish Integrated Crop Management organisation which has the objectives of demonstrating and learning from action programmes carried out on 16 reference farms. The aims are to reduce adverse environmental effects of crop cultivation, produce high quality products and develop a resource-efficient agriculture with sound economics. There are strong similarities with LEAF, the corresponding organisation in UK (Törner & Drummond, 1999).

In the Rules for IP the use of a Bio-bed is recommended as a measure to eliminate those risks with pesticides which relate to filling and cleaning the sprayer. The Bio-bed was developed by "Odling i Balans" in cooperation with the Swedish University of Agricultural Sciences. The Bio-bed is the construction of a safe place where all pesticide spillage or surplus pesticides can be quickly broken down by the presence of micro-organisms in a mixture of humus rich soil, chopped straw and peat mould (www.odlingibalans.com).

EUREPGAP

The Euro-Retailer Produce Working Group (EUREP) has presented a framework for Good Agricultural Practice (EUREPGAP) for the production of horticultural products (www.eurep.org). It defines the minimum standard acceptable to the leading retail groups in Europe, and should be used as a benchmark for existing IP standards. With regard to crop protection EUREPGAP is a means of incorporating IPM into agricultural production. The Swedish retailers and the certification body are working for the introduction of EUREPGAP and the intention is to co-ordinate the Swedish IP rules with this certification system.

The crop protection measures already required or recommended in the Swedish rules for IP reach the EUREP standard and more. One reason for this is the strict attitude to pesticide registration in Sweden with the result that no nematicides, chemical soil sterilants or any post-harvest treatment with chemicals are allowed.

IOBC

The IOBC (International Organisation for Biological and Integrated Control of Noxious Animals and Plants) has principles, minimum standards and guidelines for Integrated Production (El Titi, *et al.*, 1993). IOBC promotes the harmonisation of regional IP guidelines throughout Europe. Guidelines are available for arable crops and for the whole fruit sector (Boller, *et al.*, 1997). IOBC also intends to publish IP guidelines for field vegetables.

The IOBC Guidelines have influenced the Swedish IP work for apple production to a great extent and the rules are harmonised. If the IOBC Guidelines for field vegetables are comparable to those for arable crops then the standard of crop protection will meet IPM status. Measures to promote biodiversity and ecological infrastructures are mandatory (minimum 5% of the entire farm must be an ecological compensation area). Crop rotation will also be mandatory. Many Swedish vegetable producers, especially those with vegetables in combination with arable crops, will be able to live up to the IOBC IPM standard. Large specialised vegetable and salad enterprises, however, will have difficulties in meeting these requirements.

SOME OBSTACLES ON THE WAY TO IPM IN IP PRODUCTION OF VEGETABLES

Crop protection practices in IP vegetables should be channelled towards Integrated Pest Management techniques. Vegetable growers would like to be able to fulfil these demands but for various reasons they are unable today to do so for all crops.

In IPM preventative measures must be the foundation, with crop rotation as a key factor, for guaranteeing sustainability. In IP crop rotation is only a recommendation which is easily met in the production of those vegetables that is highly mechanised and grown in rotation with arable crops. Examples are carrots and onions. In labour intensive crops, such as salad crops that are often grown intensively, crop rotation is poor because of the lack of suitable soils within given farms, fixed irrigation systems and for economic reasons.

Forecasting/warning methods must be used in IP if available. Only two methods are validated for Swedish conditions and are available commercially; those for cutworm (*Agrotis segetum*) and carrot rust fly (*Psila rosae*). Models, based on climatic data, for forecasting infection of diseases will come. A model has been adjusted and tested for onion downy mildew (*Peronospora destructor*) and IP growers are recommended to take part in this developmental work. Few threshold levels for pests and diseases have been produced for Swedish conditions, why applying chemical control as soon as pests are seen on the crop can be justified.

The choice of plant protection products should be restricted to those which are safe both to the environment and humans. The grower, however, often has no choice, as the range of pesticides registered for use in vegetable crops is very narrow. In reality, the requirement in IP that only legally registered compounds can be used, is the same as for conventional vegetable production. With a narrow range of pesticides it is difficult to use a strategy for avoiding pesticide resistance. Biological control agents suitable for field use in vegetable crops are, at present, restricted to *Bacillus thuringiensis*.

Programmes based on repeated spray applications are accepted in IP if there are no realistic alternatives. The carrot psyllid (*Trioza apicalis*) is a pest in areas with coniferous trees. The alternative to repeated sprays is to cover the carrots with insect net, which is difficult in large fields. Repeated spray applications are common if crops are threatened by pests that will contaminate the product or lower the quality. For control of downy mildew in onion, lettuce and cucumber, repeated applications of fungicides are required. Forecasting methods will soon be introduced, but to be fully utilised these are dependant on curative fungicides.

Resistant cultivars should be used. Growers select cultivars based on market preferences, experience and information from seed companies. Resistant cultivars, if available, must meet the yield and quality of the standard ones. Strategies for securing a long life for cultivars with race-specific resistance are needed.

Band treatment with pesticides is recommended. In many cases band application is an effective way to reduce use and risks with pesticides. This is, however, seldom used by growers, although proven to be effective. The high price of the band-sprayer and the fact that the spraying operation is more time consuming might be the simple reason for this lack of uptake.

CONCLUSION

The way towards IPM has been set: The growers' own organisation has established rules and recommendations for the production of vegetables and has the intention of tightening them towards safer methods as, and when, such methods are developed. The intention of IP is in line with the goals set by the Swedish government. Programmes for educating farmers have been organised. An independent organisation is responsible for the certification procedure and controls the documentation of the production practices.

The difference between IP and conventionally produced field vegetables in Sweden is, with regard to crop protection, not very big today. This can be explained by the continuous tightening of laws and legal restrictions, which is mandatory for all growers, and the lack of sufficient IPM tools. Documentation and traceability give added value to the IP produce.

To raise the IP concept to meet the true IPM standard, an increase in applied research will be needed to give the growers possibilities to practice IPM. Growing-strategies based on preventative measures must be developed to reduce the need for pesticides and to compensate for the reduced availability of pesticides in vegetables. Strategies for the use of the pesticides must be improved, preferably in combination with forecasting methods, thresholds etc. These strategies must also have a holistic approach and include the complex of weeds, pests and diseases and also include alternative methods. Results from research and development in organic farming must be incorporated in IP. To help IP reach the level of IPM the advisory service to vegetable growers must be improved. Sustainability and IPM is threatened by the current trend towards larger and more specialised farms, driven by economic factors and a limited supply of suitable soils. The economics of the production process must in some way be improved, since most proposals for IPM cost time and money.

REFERENCES

Anderson L; Gabring S; Hammar J; Melsäter B (1992). Principles for Identifying Unacceptable Pesticides. *KEMI Report* **4**, 1-34.

Anonymous (1995). *Frukt & Grönt Handbok. Quality norms for fruits and vegetables*. (In Swedish). Frukträdet, Box 5512, S-11485 Stockholm.

Boller E F; Malavolta C; Jörg E (1997). Guidelines for Integrated Production of Arable Crops in Europe. Technical Guideline III. *IOBC/WPRS Bulletin* **20(5)**, 1-18.

El Titi A; Boller E F; J P Gendrier (1993). Integrated Production, Principles and Technical Guidelines. *IOBC/WPRS Bulletin* **16(1)**, 1-38.

EU (2002). http://europa.eu.int/comm/food/fs/ph_ps/pro/eva/existing/exis02b_en.pdf

SJV (1998). Reduced risks connected with the use of pesticides. Results from the programmes 1986-1996. The Swedish Board of Agriculture. (In Swedish). *Jordbruksverket, Report* **9**.

SJV (2002). Programme for the use of plant protection products in the agriculture for the period 2002-2006. The Swedish Board of Agriculture. (In Swedish). *Jordbruksverket, Report* **7**.

Törner L and Drummond C J (1999). Integrated Crop Management: On-farm experience in Sweden and the UK. *The International Fertiliser Society. Proceeding* **443**, 1-42.

ICM – what does it offer – profits, markets, environment, social benefits?

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ABSTRACT

Integrated Crop Management offers some real benefits for the individual farmer and the industry as a whole. However, managing the system requires vision, knowledge and a challenging mind. This paper will focus on the adoption of ICM at a farm level, the available tools for the farmer and the requirements of the market place including the Assured Produce Scheme, EUREPGAP and the LEAF Marque. It will also discuss some of the realities behind a profitable farming system, which aims to deliver an environmentally responsible approach and aims to address some of the broader social issues affecting the industry - from employment to the local community.

INTRODUCTION

Integrated Crop Management is an approach in which the farmer seeks to produce safe, wholesome food through the efficient management of fresh produce, arable crops and livestock while conserving and enhancing the environment and remaining economically viable. In particular it is geared towards sustaining and optimising the use of all resources on the farm, including soil, water, air, staff, machinery, capital and wildlife habitats, landscape and archaeological features. Its successful uptake requires a detailed understanding of the farm business and an innovative and challenging approach. Built around existing knowledge and sound husbandry principles, many of the practices are constantly being improved in accordance with the latest research and new technology. This encourages farmers to review their current practices and make appropriate changes.

ICM has developed throughout Europe as a whole farm management approach. ICM has been the framework from which some of the farm assurance schemes have been developed such as the Assured Produce Scheme (APS) in the UK, EUREPGAP throughout Europe and the development of the LEAF Marque. It would be fair to say that in the field vegetable sector the need to demonstrate ICM principles has been accentuated by the involvement of the retailer sector in order to differentiate the market and demonstrate care of production methods to their consumers. In addition, New York farmers have experienced parallel pressures, including horticultural, economic, social and political ones, to reduce the environmental impact of farming, and use of pesticides in crop production (Cornell, 2002). Public concerns with nutrient and sediment movement into ground and surface water are growing. So ICM provides an ideal approach.

However market requirements and drive must be backed up by science, technical innovation and farmer uptake. As part of a planned strategy to encourage the uptake of ICM in 1991 LEAF started to select its first demonstration farms, as examples of 'best practice' in terms of attention to detail in all practices. These demonstration farmers are commercial farms who are committed to challenging their practices and telling others about what they are doing, in particular encouraging others to make change. The farmers are proud of their methods of production and interestingly the need to reconnect with the consumer has been the most rewarding to the farmer.

SEARCHING FOR A VISION

Since the profitability of fresh produce businesses vary widely, farmers wanting to do well have to ensure that the performance of their business moves towards that of the best and that markets are secured. While some issues are outside their control, all businesses, whatever their climate or geographical position, can improve their performance in some way. Individual farm businesses obviously ultimately take responsibility for their own performance but there is a need to improve the advice available to the industry. It must concentrate on increasing the competitiveness of businesses, combining the best technical farming advice with high quality business support.

In the UK the last 10 years have seen an improvement in environmental management on farms, through better risk management and positive habitat creation (Countryside Agency, 2002). Furthermore the development of pesticide resistance in key pests, registration of fewer and more expensive new chemicals for pest control, loss of existing products and increased competition on a global scale is pushing more farmers to look for chemical alternatives, and ICM provides a logical approach for them to consider. Specifically some of the practices which reduce the reliance on chemicals include site selection, crop specific production strategies, nutrient management and cover cropping.

In an ICM vegetable programme it is important to accurately identify pests and assess their abundance. A knowledge of the biology and ecology of the pest(s) attacking the crop and factors that can influence crop infestation is required, together with an understanding of the influence of weather and natural enemies. Following an ICM programme may mean that the farmer needs to be confident enough of the decision made to take risks to suppress pest populations to levels that do not cause economic damage rather than total eradication of a pest. The former situation, however, is not always acceptable from a market point of view and there is a need to educate the public and policy makers about ICM to improve their understanding of food production, processing and marketing systems and for the market to accept produce with blemishes.

THE MARKET

The objective of the farm assurance schemes is to address the concerns and needs of consumers, retailers, processors and growers for safe food of good quality at affordable prices, whilst maintaining a profitable and competitive UK horticultural industry. This is achieved by the application of scientifically based ICM i.e. good horticultural practices with emphasis on reducing whenever possible the use of pesticides, optimum use of fertilisers and improved protection of the environment. The APS protocols describe best existing production practice, highlighting integrated pest, disease and crop management systems for each specific crop - they are not intended to be a 'growers' guide' but they do outline current commercially acceptable best practice.

Ultimately it is hoped that by taking a basic approach everyone involved will come to understand the problems of safe and economic production, and the protocols can be used as a technology transfer vehicle for the industry. Like APS, EUREPGAP promotes the same best practice standards and reflects the desire to incorporate ICM into European production in co-operation with suppliers. Importantly the farm assurance schemes are not intended to replace or override existing legislation or regulatory bodies since in the UK, the safety of the consumer, operator and environment is well catered for. It is also important that they are not prescriptive. Food production is complex, crop requirements may vary from field to field and season to season and therefore guidelines to producers are based on the principles of basic primary food hygiene, crop production, organisation and training. More recently the development of the LEAF Marque in the UK will provide farmers with a further marketing opportunity, by addressing additional environmental requirements on a whole farm basis, including resource protection and additional conservation criteria. Backed by farmers and industry the use of the demonstration farms, training and management tools mean that this scheme will help farmers benefit from ICM in the market place.

DOING THE RIGHT THING, THE RIGHT WAY, FOR THE RIGHT REASONS

ICM is a management approach that requires planning and innovation and one of the hardest areas for farmers to address is the setting of priorities, this is where the LEAF Audit has been a useful benchmarking exercise. Specifically benefits that ICM offers to farmers (LEAF, 2000) include:

Profit

Through the better attention to detail demanded of a fully integrated approach it is possible to maintain, and in many instances, increase profitability, through assessing the business, targeting inputs, reducing risk and minimising waste. With issues such as the introduction of HACCP (Hazard Analysis Critical Control Point) on farm this mind-set is essential.

Environment

Farmers do care for the environment, but they need to demonstrate this responsible attitude by improvements in the quality of soil, water, air, wildlife habitats and landscape. More monitoring of these factors is required long term.

Social responsibility

ICM offers a realistic and economically viable option with benefits for the rural community, and which embraces the social responsibility of farming towards the countryside and those living and working there.

Market preference

The market demands a product that is of high quality and is grown with care and concern for the countryside. So much of British food is grown in this way but farmers need to sell that message and be prepared to prove it to the market.

Political priority

With a strong priority being given to sustainable development and much activity following the Curry Commission Report (Crown 2002) there is pressure to reduce the impact of farming practices on the environment and to improve water, soil and air quality and biodiversity. ICM offers a practical, achievable and realistic farming approach that can be adopted by the majority of farmers as a natural extension of their farm practices. ICM is increasingly seen as a positive way of addressing the issues facing governments and agriculture throughout Europe and globally.

PUTTING IT INTO PRACTICE

High levels of management skills and ability are essential for ICM in vegetable production. However, little consideration is given to 'human capital' in ICM research to date. For example, the on-farm employment effects of integrated systems are largely unexplored. One research project has indicated that staff costs are likely to increase because of training requirements and the need to employ more highly qualified staff. A lack of conclusive findings indicates that further research into the social effects of integrated systems is a key area of future work.

Farmers need more help to help themselves. There is a lot of scope to enhance and develop the interest and enthusiasm already established among the farming industry for ICM. However this requires further backing – both in terms of long term commitment and vision from Government and financial backing. ICM needs the right research, training, technology, development, demonstration and advice to support it. This includes monitoring and scouting, forecasting, determining threshold levels and management tactics.

The following three Case Studies focus on field vegetable businesses where ICM is central to the farming philosophy:

Case study 1 Barfoots of Botley Ltd, West Sussex

At Barfoots the farm mission statement is: 'To run a viable farming system which is environmentally and socially acceptable, ensures the continuity of supply of wholesome, affordable food and enhances the fabric and wildlife of the British countryside.' Barfoots of Botley grow a range of semi-exotic produce marketed as healthy living, fun foods principally through the major supermarkets. This includes corgettes, squashes, sweet corn, runner beans, pumpkins, rhubarb and wheat. Well recognised for their commitment to quality and the environment Barfoots was one of just three suppliers nationally awarded a Tesco Nature's Choice Gold Award and in 1997 the company was given " Partnership in Produce" status with J Sainsbury in recognition of its Integrated Crop Management efforts.

The soil, people and customers are considered to be their most valuable assets so every effort is taken to look after them all equally well. Skilled and competent staff make the business tick and lie at the heart of ICM. The complexities of growing a continuous supply of fresh produce whilst maintaining high standards of environmental care mean that attention to detail is essential. It all begins with the soil. Crop residues and autumn cover crops are worked in to enrich soil organic content and, before cultivations take place, conditions are assessed to minimise any damage to soil structure. By avoiding driving over the fields excessively and correctly setting tractor tyre pressures soil compaction is reduced. Soil is tested for organic matter, nitrate levels and trace elements. This information, together with an understanding of what the previous crop is likely to have taken out, is used to calculate fertiliser requirements. Advice is also taken from a qualified agronomist. Of course fertility varies within each field and by using GPS (Global Positioning Satellite) systems the amount of fertiliser applied can be varied across the field. This technique has allowed a greater accuracy and a 30% reduction in the volume used.

Case Study 2 J H Kemball & Son, Wantisden Hall Farms, Suffolk

The varied cropping of potatoes, onions, carrots, green beans, cereals, sugar beet and parsnips means a sound balanced rotation can be established. At Wantisden Hall Farms ICM means that they are continuously fine tuning and improving the good farming practices that have always been a feature of this farm. Good planning and a multi-skilled flexible workforce are absolutely essential. Regular staff meetings give everyone an insight into how the farm is managed, whilst discussion often revolves around how to implement ICM principles. Detailed crop records are vital to the management of the farm and they give customers the assurance that best practice has been followed. Well before any crop goes into the ground, staff work closely with their customers to find out precisely what is required. However, in an integrated system, it is not just customer needs which determine the cropping. Crops like potatoes and onions can be quite demanding on the soil structure and health but a carefully planned rotation, with other less demanding crops such as cereals interspersed between the vegetables, ensures the soil is kept in good condition and helps to keep weeds, pests and diseases at bay.

Case Study 3 Russell Smith Farms, College Farm, Cambridgeshire

On Russell Smith Farms crops include potatoes, winter cereals, sugar beet, onions oil seed rape, and parsnips. Again staff are considered key to putting ICM into practice. Whilst efforts are put into the need to control costs, strong recognition and value is given to the contribution skilled people can make. Over the last 12 years, they have doubled their full time staff and tripled the casual workers.

Quality assurance schemes such as Assured Produce, Nature's Choice and, latterly, the Assured Combinable Crops Scheme, mean that attention to detail is fundamental. The complexities of growing high quality vegetable crops whilst maintaining high standards of environmental care requires finely tuned management. ICM begins with the soil. The light soils are ideal for growing fine quality root crops including potatoes, onions, parsnips and sugar beet for the supermarket customers.

Every effort is made to reduce the need for crop sprays. A well-balanced crop rotation helps to prevent weed, pest and disease build-up with winter wheat, oilseed rape, forage rye and winter barley acting as breaks between the vegetables. College Farm takes on additional land each year to extend the rotation. Disease pressure in the vegetables are reduced by growing two or three varieties with different resistance ratings and monitoring is key to the attention to detail demanded by an ICM system. For this reason weather forecasting, the use of diagnostics and managing the crops in conjunction with a team of BASIS and FACTS trained agronomists is considered crucial.

These case studies demonstrate the forward-looking nature of the individual businesses involved. The farmers have adopted a whole farm approach and adopted a combination of long and short term production strategies to maximise their net profit while minimising risks of undesirable environmental impacts of practices. A strong emphasis is placed on staff and soil management and with regard to pests and diseases multiple control tactics are used to minimise the risk of pests adapting. This allows the farmers to choose the most environmentally sound, efficacious and economically efficient pest management programme for their situation.

The farmers use trained agronomist and indeed an increasing amount of farmers are becoming BASIS trained allowing more accurate assessment and identification of pests and diseases. Regular monitoring, the use of insect traps to identify when scouting should be intensified or control measures taken is all critical. Added to this weather data is becoming increasingly more accurate and more farmers now have access to web-based information allowing access to weather and regional forecasts. Simple weather recording equipment such as thermometers, hygrometers and rain gauges placed in vegetable fields will assist the prediction of pest outbreaks.

The key to successful ICM implementation is in the management. Appropriate management tactics to control pests include cultural, biological, and physical controls, as well as chemical controls when they are needed. Taking advantage of some of the simple and relatively inexpensive pesticide alternatives can result in significant savings to growers both in terms of pesticide use and crop loss. Often a thoughtful preventative measure, such as the selection of disease tolerant or resistant cultivars, taken before the crop is planted can result in significant savings of crop rescue treatments later in the season. Furthermore records kept from year to year on pest occurrence in fields can be valuable tools for avoiding pests in the future. Ultimately it is about taking a logical and planned approach across the farm to reduce risk and enhance the environment, for the benefit of the business, the environment and ultimately the customer.

CONCLUSION

There are several incentives that change farming practices, which include a system that works and is practical, that saves money and meets market requirements. Integrated Crop Management is such an approach. It is one of the most realistic ways forward for the majority of farmers. It provides a logical framework to satisfy the mixed requirements demanded of farmers, to deliver a profit, satisfy the market and demonstrate environmental and social benefits

REFERENCES

Cornell (2002). *Integrated Crop and Pest Management Guidelines for Commercial Vegetable Production*, Cornell Co-operative Extension Publication.

Countryside Agency (2002). *The State of the Countryside 2002 - working for people and places in Rural England.*

Curry (2002). *Farming and Food – a sustainable future.* Report of the Policy Commission on the Future of Farming and Food January 2002.

LEAF (2000), *The LEAF Handbook for Integrated Farm Management – a practical guide for the adoption of integrated farming.*

Slugs in vegetable crops: Can control methods meet the needs of growers and consumers?

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ABSTRACT

Slugs are a persistent pest in vegetable crops. Consumers impose very high quality standards such that any pest damage or traces of pesticides can lead to rejection of crops by retailers. As part of a LINK project we are investigating ways of minimising damage and pesticide use by using approaches to slug control that have been developed in arable crops. The requirements of growers and advisors for decision support have been established. In addition to readily accessible information about the pest species growers require decision support tools for both short term and long-term prediction of slug pest problems. Some of these requirements can be addressed from existing knowledge, but others need new research. Information on the pest species, the timing of damage, and novel approaches to control are discussed, focussing on two contrasting horticultural crops, lettuce and brussels sprouts.

INTRODUCTION

Slug damage is extremely costly for UK Horticulture. In field crops alone, the damage is estimated at over £8 million, with applications of molluscicides exceeding £60,000 per annum. Moreover, the problem is increasing. With continual development and growth of the 'ready washed vegetable' and 'ready made meal' markets, supermarkets and their customers are increasingly sensitive to damage and contamination by live slugs or molluscicide pellets. Whole consignments of salads and vegetables can be rejected because they fail the stringent quality control employed by the retail or processing industry, resulting in a substantial loss in revenue and reputation to the grower.

It is imperative, therefore, to reduce slug damage and molluscicide use in horticultural crops. In recent years there has been a considerable amount of research into the slug problem in arable crops and, as part of a Horticulture LINK project we are extending this work to slugs in vegetable crops. To do this we have focussed on two crops, lettuce and Brussels sprouts. Lettuce has a short growing cycle and action against slug damage needs to be taken either before or soon after planting. Damage by slugs is most serious at the beginning and end of the growing season and may be exacerbated by the use of polythene or fleece covers. Brussels sprouts have a long growing season with slug damage occurring shortly before harvest; there is considerable potential for slug populations to recover from treatments applied before or soon after planting. Therefore techniques for monitoring the build-up of slug populations during the growing season are required together with techniques for preventing slug damage by applying treatments to the base of the maturing crop canopy or to soil beneath the canopy, shortly before the crop reaches the susceptible stage.

WHAT THE INDUSTRY WANTS

Focus group meetings were held with growers and consultants to examine the nature of the slug pest problem. The meetings identified a large amount of information that may be considered when making slug management decisions. Discussions highlighted the need for tools to (i) predict the changes in slug populations (ii) predict the impact of the slug population on a crop and (iii) indicate the best rate and timing of treatments to control the problem. A requirement for basic, background information on control products, non-chemical control methods and crop varieties was also indicated, as was information on slug biology and behaviour.

WHAT THE RESEARCH CAN DELIVER

Background information

Whilst there is a considerable amount of material to address the requirement for more background information, it is very scattered. Information on control products is available from manufacturers and suppliers. Data on non-chemical control methods, such as cultural methods and biological controls is often in research papers or text books (Godan, 1983; Port *et al.,* 2000; Barker, 2002) as is information on slug biology and behaviour (Runham & Hunter, 1970; Port & Port, 1986; Barker, 2001). Clearly this information needs to be distilled into a readily accessible form and there will need to be some objective assessment made of alternative control strategies where possible.

One difficulty in collating appropriate information is that there has been no systematic assessment of the species of slug causing damage to horticultural crops. There are over 30 species of slug in the UK, yet, for example, only a few species cause problems in arable crops. A preliminary objective of our research was to assess the species found causing a problem in lettuce and Brussels sprouts crops. We assessed slug species and numbers by using shelter traps (upturned plant pot saucers) baited with chicken food (layers mash) at a range of sites. The species found most frequently was the field slug *Deroceras reticulatum* (Müller). As *D. reticulatum* is the most frequently encountered pest species in arable and other crops there is a considerable amount of published information that we will use to produce the background information required.

Trap or treat

A tool to indicate the best rate and timing of treatments to control the slug problem is required by growers. The application rates recommended by the manufacturers of pellets have been identified following field trials, but there is little published information on the efficacy of different application rates. Trials that have been done in a variety of crops have usually shown there to be no significant difference in the level of control achieved with different application rates. Making two applications at half rate may have the advantage of prolonging the presence of pellets in the crop, but there are no data on whether this will give better control and the application costs will be doubled.

Treatments may be timed in the short term e.g. in relation to weather conditions, or in the long term in relation to development of the slug population. We will deal with the latter strategy in a later part of this paper; however the influence of weather conditions on activity is well known and is important in affecting whether slugs are available to trap or to treat. In arable crops *D. reticulatum* is most active when the overnight air temperature is above 9°C and below 20°C, and when the soil surface is moist (Young *et al.,* 1993). We are testing whether similar thresholds for activity apply in lettuce and Brussels sprouts with the aim of producing a short term forecast of when slugs will be active. When activity is predicted then it would be advisable to trap (to assess the activity-density of the slug population) or to treat (if slugs are present and if there is a crop requiring protection). A decision tree for using a forecast of activity to identify times to treat is shown in Figure 1. Targeting activities, based on the weather conditions, will reduce the time spent on assessing slug populations and will reduce unnecessary pesticide use.

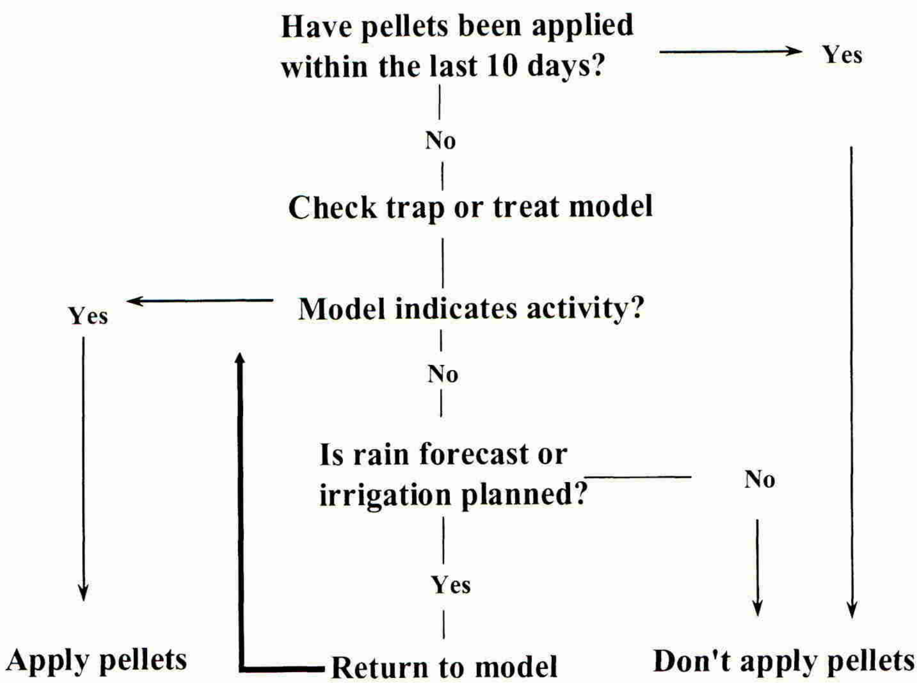

Figure 1. A decision tree for using a forecast of activity to identify times to treat. A modification of this decision process would be used for trapping.

Impact on the crop

The slug problem in arable crops is largely a consequence of slugs feeding on seeds or seedlings. In both cases the plant is usually killed. Damage to plants beyond the seedling stage, whilst obvious, is rarely of economic importance (Glen *et al.* 1992).

In horticultural crops damage to seeds or seedlings is also important, but the greatest problems occur after planting. In lettuce crops the losses are more often due to contamination of the plant by slugs or slug products (mucus and faeces) and the damage threshold above which the crop is "lost" is so low that feeding damage causing a progressive loss of leaf area is rarely a consideration. As a consequence there is little scope for modifying the approaches to control dependent on pest numbers. A zero tolerance approach is required.

In Brussels sprouts, slugs move onto the plant and damage the buttons. The more buttons that are damaged the more chance there is of the crop being downgraded after harvest. However, the complex relationships between the numbers of damaged buttons, the slug populations and the weather have not been elucidated. Rather than establishing a threshold number of slugs above which damage is expected, it is likely that the strategy will be to identify the appropriate timing for control measures such as pellet application to minimise the risk of slug damage. Thus the present research is not going to predict the direct impact of the slugs on the crop, but will be used to minimise economic losses.

Changes in slug populations

A persistent problem for growers is knowing how the numbers of slugs present at a site will change over the following weeks and months. When planning to use a piece of land the facility to predict slug populations would be a valuable management tool.

To tackle the problem of long term forecasting Newcastle University and IACR Long Ashton have developed a framework for modelling the population dynamics of slugs to explain and predict effects of weather, farming practices and the role of predators, parasites and pathogens in arable crops. We have developed models which simulate changes in populations of slugs taking into account growth rates, fecundity and mortality together with meteorological data (Shirley *et al.*, 2001). The model was developed for arable crops and needs to be modified to take account of the different conditions pertaining in selected horticultural crops. However, we anticipate that the output (Figure 2) will allow growers to decide whether the slug problem predicted will require interventions and the scale on which these will be required.

WILL THE CONTROL BE ADEQUATE?

Given the very low damage thresholds in crops such as lettuce it is likely that no suite of control measures will give total control of slug pest damage. However, the aim of this project is to reduce losses as far a practicable without incurring substantial further costs. In crops such as lettuce the improvements to monitoring and prediction of populations will allow growers to avoid using land that is likely to have a large slug problem when the crop is being grown. If control measures such as molluscicide pellets or nematodes are to be used the treatment can be timed to give optimum effect. Where damage is a problem later in the growth of the crop, such as in Brussels sprouts the decision support models will allow growers to time their treatments to avoid periods of adverse weather and will predict the effects of different control strategies.

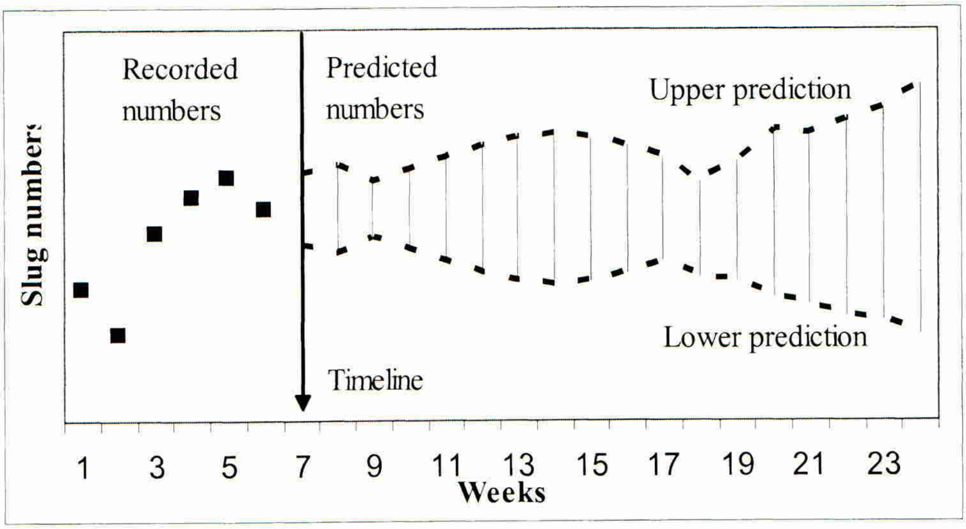

Figure 2 Schematic diagram of part of the output from the Decision Support System. The diagram shows historical records of slug numbers recorded and the probable upper and lower limits of predicted populations.

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REFERENCES

Barker G M (Ed.) (2001). *The biology of terrestrial molluscs*. CABI Publishing: Wallingford.

Barker G M (Ed.) (2002). *Molluscs as crop pests*. CABI Publishing: Wallingford.

Glen D M; Wiltshire C W; Milsom N F (1992). Some aspects of forecasting slug damage in arable crops. *Journal of Medical and Applied Malacology* **4**, 147-152.

Godan D; Gruber S (1983). *Pest slugs and snails. Biology and control*. Springer-Verlag, Berlin.

Port C M; Port G R (1986). The biology and behaviour of slugs in relation to crop damage and control. *Agricultural Zoology Reviews* **1**, 255-299.

Port G R; Glen D M; Symondson W O C (2000). Success in Biological Control of Terrestrial Molluscs. In: *Biological Control: Measures of Success*, eds G Gurr & S Wratten, pp. 133-157. Kluwer: Dordrecht / Boston / London.

Runham N W; Hunter P J (1970). *Terrestrial slugs*. Hutchinson University Library, London.

Shirley M D F; Rushton S P; Young A G; Port G R (2001). Simulating the long-term dynamics of slug populations: a process-based modelling approach for pest control. *Journal of Applied Ecology* **38**, 401-411.

Young A G; Port G R; Green D B (1993). Development of a forecast of slug activity: validation of models to predict slug activity from meteorological conditions. *Crop Protection* **12**, 232-236.