Campden BRI
Station Road
Chipping Campden
Gloucestershire
GL55 6LD, UK

Tel: +44 (0)1386 842000
Fax: +44 (0)1386 842100
www.campdenbri.co.uk

Sustainable Crop Protection

Pesticides are a vital tool for farmers and growers to enable the production of economic yields of marketable crops which meet the requirements of the supply chain. Legislative developments have resulted in a reduction in the number of pesticide products available for use by the industry. Further restrictions on the maximum residue level of pesticide permitted on foods are also limiting choices available for effective crop protection. Whilst these changes have focussed on consumer safety, the most recent legislative development is concerned with the conditions under which pesticides are used in the field.

This white paper looks at that problems that farmers and growers face, and the various ways they can modify their practices to comply with legislation and, more broadly, to meet the goal of reducing the use and environmental impact of pesticides and improving the sustainability of crop protection practices. Particular examples cover weed control, disease control (using potatoes as an example), the use of beneficial insects, and pesticide application techniques.

To discuss any of the issues raised in this report, please contact:

Richard Stanley
+44(0)1386 842004
richard.stanley@campdenbri.co.uk

Campden BRI, Registered no. 510618, Incorporated in England & Wales
Registered Office: Station Road, Chipping Campden, Gloucestershire. GL55 6LD
Part of Campden BRI Group

Legislation

The Sustainable Use Directive (SUD) (2009/128/EC 'Establishing a framework for community action to achieve the sustainable use of pesticides') specifies a number of measures which must be adopted by the Member States to reduce the impact of pesticide use on human health and the environment. The main points can be summarised as follows:

- **National Action Plan** (NAP). Member States must identify objectives, measures, targets and timetables to reduce the risks from and impacts of pesticides. This must encourage the introduction of alternative approaches that reduce the dependency on pesticides, and should include indicators which monitor the use of pesticides of particular concern.
- **Training.** Professional users, distributors and advisors must have access to appropriate training. Evidence of training must be provided by a system of certification.
- **Application Equipment.** Application equipment in professional use must be subject to inspection at regular intervals. This is specified as not less than 5 years until 2020 and every 3 years after then. Evidence of inspection must be provided by a certification system.
- **Aerial Spraying.** This is prohibited unless approval is requested and obtained from the competent authority
- **Sales of pesticides.** Sale of products authorised for professional use is restricted to persons holding a certificate of competence.
- **Protection of drinking water.** The aquatic environment must be protected, by giving preference to pesticides classified as less dangerous in this situation, and by the use of mitigation measures to protect waterways, such as buffer zones that will minimise drift and run-off.
- **Specific areas.** In areas used by the public, such as parks, sports grounds, and school grounds, and in the vicinity of healthcare facilities, pesticide use should be minimised or prohibited.
- **Handling of pesticides.** Professional operators must not endanger human health or the environment during the following storage, handling, dilution of pesticides, handling of packaging and remnants, disposal of tank mixtures after use, and cleaning of equipment.
- **Integrated pest management (IPM).** All necessary measures must be taken to promote low pesticide input systems and non chemical methods, including organic farming. Member States should support the necessary conditions for IPM with information, tools and advisory services.
- **Indicators.** Harmonised risk indicators must be established, and trends and priority items such as active substances, crops and regions identified which require attention.

Integrated pest management

This is probably the most significant and far-reaching aspect of the SUD. Useful guidance on the way in which IPM might be applied to specific crop/pest situations is provided In a European Commission report which was published in advance of the publication of the SUD. The report summarises the principles of IPM and identifies the need to differentiate between providing general guidance on integrated methods of crop management and the importance of developing crop specific information. Guidance developed at a crop level will enable growers to identify solutions to pest, disease and weed problems which relate to the immediate problem which confronts them.

A clear definition of IPM is difficult to establish as different solutions are needed for different crops and climates. In fact the concept is defined by eight general principles which are identified in Annex III of the SUD; these are related to the following topics:

(1) Measures for prevention and/or suppression of harmful organisms
Emphasis on creating conditions that reduce the extent of pest damage; for example, cultivation, crop rotation, resistant cultivars, correct fertiliser, irrigation practice, good farm hygiene, field margin management to promote beneficial insects.
(2) Tools for monitoring
Systematic crop observation will enable early diagnosis of problems. This allows forecasting and warning systems to be applied to similar crops in the region.
(3) Threshold values as basis for decision-making
The decision to apply crop protection chemicals should be based on robust and scientifically sound threshold values. These may need to be defined for region and crop specific situations. Threshold values may be more appropriate for insect pest control decisions and less appropriate for decisions on disease and weed control. This is particularly true in situations where a disease may infect the crop in a sequence of more than one outbreak during the same season.
(4) Non-chemical methods
This approach is to be used if it results in satisfactory control of pests. This is not applicable in all situations, but there are opportunities for weed control using suppressive fabric mulch, cultivation techniques such as stale seedbeds and guided precision hoes in row crops.
(5) Target-specificity and minimization of side effects.
Selection of pesticide products that have a minimal effect on human health and the environment. This requires detailed knowledge of the fate and behaviour of the products. This has been a successful approach in response to crop specific problems, such as in the fruit growing regions of Northern Italy. In this case unacceptable residues on fruit and further detections in the environment were identified. The quantity of pesticides applied was reduced and the most harmful chemicals were excluded during a long term programme of change between 1990 and 2010.
(6) Reduction of use to necessary levels.
In an integrated crop management environment, which includes pest reduction strategies described in points 1-5, the reduction of pesticide application rates is not likely to be associated with increased resistance to the pesticide. Lower dose rate applications can be made in proportion to observations of pest populations and crop canopy.
(7) Application of anti-resistance strategies.
Resistance management should include the use of a range of pesticides, each with a different mode of action, where these products are commercially available. Anti-resistance strategies can also include the combination of pesticide applications and non chemical strategies such as crop rotation.
(8) Records, monitoring of applications, documentation and check of success of control.
This will require records of the use of risk mitigating policies such as training and calibration and testing of sprayers, but will include evaluation of the level of control of pests and diseases and weeds in commercial crop situations, using agreed criteria.

The report evaluates the way in which growers should respond to the provisions of the SUD by presenting a case study example. In any given crop protection scenario the farmer must be aware of non chemical plant protection measures to comply with the general requirements related to principle 4 in national legislation. The way in which compliance is achieved is to correctly identify the treatment for a particular crop and a particular pest. Threats to crops by pests will involve different plants and different pests, each requiring a different solution.

In order to enable professional users in all Member States to comply with general IPM principles it will be necessary to communicate these principles in a similar way to that in the Sustainable Use Directive.

In addition professional users must be able to obtain guidance at a crop specific level provided by a suitable advisory service. What is also important on a national level is that Member States should plan to provide professional users with the opportunity to take part in IPM training activities, field meetings, workshops or similar activities.

There is no doubt that a number of crop protection decision support models have been developed and validated by research programmes in several Member States. However, the challenge will be to disseminate this information and encourage the adoption of an approach based on pest identification and threshold monitoring in commercial crops throughout the EU.

Challenges to weed control

The number of herbicide products available for weed control in root crops and alliums has been restricted due to the loss of approval for cyanazine and metoxuron in 2008. Vegetable crops were further disadvantaged by the loss of trifluralin and propachlor in 2010. During this time growers have adopted more integrated approaches, with hand and mechanical weeding being used.

Non chemical weed control

There have been a number of developments of specialist machinery capable of removing weeds; the most well known commercial product is the tractor mounted precision guided hoe. Developed for use in row crops such as brassicas and salads, these hoes can remove weeds from between rows and within rows of drilled or transplanted crops. Weed plants are detected using either cheaper infra red or more costly camera guided systems. The visual information is processed to activate the movable hoes, which are positioned by compressed air systems. One UK manufactured machine (Robocrop) has sophisticated camera/processor combinations and a spinning blade. Over 250 of these machines are in use in Europe. Further developments by other manufacturers include cameras and lights to eliminate shade effects, enabling the machines to be used at night.

Electrical weeding

Electrical weed control technologies are also on the market; these have been developed to apply 5KV of electric charge to problem perennial weeds like thistles, docks and nettles using a hand held lance. There are advantages to this approach when herbicides are not an option, such as in areas with public access; some trials have been conducted on organic blackcurrant crops.

Flame weeding

Alternative strategies include flame weeding in carrot crops; this requires careful monitoring and accurate timing to apply a gas powered flame to weed seedlings which have emerged before the carrot crop has germinated.

Hot water

Another novel development uses hot water combined with foam to control weeds. A tractor mounted electrical generator is used to heat a tank of water to 90^{o} C; this is applied with a foam wetting agent to the weed plants. The Foamstream equipment won an innovation award at the 2012 LAMMA show.

Cultivation

A more traditional weed control option available to farmers is to integrate a herbicide strategy with a cultural technique known as a stale seedbed; this exploits the time available between harvest of one crop and drilling of the next. When using this technique the seedbed is prepared but drilling of the crop is delayed while the weed population emerges and the seedling weeds can be removed by spraying or cultivation before drilling of the crop.

Control of grass weeds: an example of the technical challenge to arable growers

Control of grass weeds in arable crops is a good example of the difficulty of overcoming resistance problems. Blackgrass and bromes are a problem weed in arable crops like cereals and oilseed rape. At low grass weed populations of fewer than 100 heads per square metre, products containing the sulfonylurea herbicides such as mesosulfuron and iodosulfuron are adequate to control the problem. However, in many areas the grass weeds are becoming resistant to these widely used products due to increased levels of enzymes in the weed plants which are able to break down the herbicide. As a result many arable crops have developed a serious grass weed problem. This has led to the use of additional chemicals such as flufenacet, propyzamide and carbetamide, which are used sequentially in an approach known in the arable sector as stacking. However, this has led to concerns that wider use of some of these products, particularly in the winter months, will leave unacceptable residues in watercourses. The two herbicides, isoproturon (IPU) and trifuralin, had been consistently found in watercourses at levels which exceeded those set by the Water framework Directive. As a result their authorisation was withdrawn in 2009. Prior to withdrawal, IPU was the most widely used herbicide in the UK.

To avoid the use of those chemicals most likely to leave residues in water, some growers are returning to older chemicals such as tri allate, and napropamide and metazachlor.

Many farmers are now integrating the herbicide strategy with cultural techniques such as stale seedbeds; this exploits the time available between cereal harvest and autumn drilling. The seedbed is prepared but drilling of the crop is delayed while the weed population emerges and can be removed by spraying or cultivation before the drilling of the crop.

Biological control of Japanese knotweed

Japanese knotweed *Fallopia japonica* was introduced into the UK from Japan as an ornamental plant in the 1800's. Due to the highly invasive nature of this plant it has spread throughout southern UK and is smothering vegetation in riverbanks, canals, railway embankments, road verges and hedgerows. It causes damage to buildings as it can push through tarmac and even concrete. Where it is present developers must remove soil for incineration before construction can begin. Control of the plant using herbicide sprays and mechanical removal has not been successful in stopping the invasive spread of this weed. Under the Wildlife and Countryside Act 1981, it is illegal to cause the plant to grow in the wild. A co-ordinated 5 year project which included CABI, local authorities, and stakeholders in rail and waterways was set up to identify a biological method to control the plant. After extensive studies which investigated the pest species which feed on the plant in its native habitat in Japan, an insect was identified with the potential to selectively feed on Japanese knotweed without affecting other native plants in the wild.

The psyllid was collected by researchers in Japanese knotweed's native range in Japan. It lays its eggs on Japanese knotweed and the young then feed on the sap as they develop, reducing the plant's ability to grow and spread. Tests have confirmed that it will not significantly feed or reproduce on any other plants, even if it is presented with no other choice, so it should not pose a threat to our native plants and wildlife.

Agreement was reached to test the effectiveness of the psyllid insect on a larger scale. In 2010 the controlled release of the psyllid *Aphalara itadori* was authorised at a small number of carefully selected sites containing Japanese knotweed in England and Wales. These sites, together with a number of control sites on which the psyllid has not been released, are being closely monitored. The locations of the release sites and the control sites has not been disclosed in order to maintain the integrity of the ongoing research.

Challenges with potato diseases

Blight

One of the most damaging disease threats to the potato crop is blight caused by a fungal infection of *Phytophthora infestans.* The effects of blight on leaves and tubers cause extensive economic loss and must be prevented by a programme of foliar applications of fungicide. The spread of blight spores from sources of infection is dependent on weather conditions, particularly periods of high humidity.

There has been some success in predicting an increased threat of infection by monitoring the changes in temperature and humidity in the crop. Extensive investigations into the life cycle of *Phytphthora* have identified a set of conditions, known as a Smith Period, which is required for the disease to proliferate. This is at least two consecutive days where the temperature is 10°C or above and on each day at least 11 hours when the relative humidity is greater than 90%. When these conditions exist blight will spread unless fungicide sprays are applied.

One prediction system, called Plant Plus, provides decision support for potato blight spray applications; it was developed in the Netherlands and has been marketed in the UK by companies specialising in software marketing for the agriculture sector. The Plant Plus system is based on historical and forecast weather data. In addition, details of variety susceptibility, leaf area/crop cover, local conditions and fungicide application history of the crop is included. When the system was first introduced it was promoted to the UK potato growers by pesticide manufacturers who were marketing blight fungicides.

Most UK growers would use a monitoring service available on the blightwatch.co.uk web site, which sends a postcode based alert when blight risk is high and a Smith period has been recorded.

Varietal resistance to blight exists in some varieties such as Sarpo, but market acceptance of the variety is low due to poor flavour and low yields. Most commercially grown varieties have been selected for market characteristics such as yield, earliness of cropping, tuber size and shape, dry matter content and dormancy

Despite this valuable decision support information for disease control, the potato crop also has a critical need for water if economic marketable yields and size grades are to be attained. As a result there is often a conflict between fungicide applications and irrigation scheduling. For example if it takes 3 days to complete an irrigation run through a crop then a spray cannot be applied until the sequence is complete and the foliage is dry. If irrigation is on a weekly schedule it is difficult to change the interval between spray applications from 7 to 10 days as it will clash with the irrigation needs of the crop. About 35% of the potato crop in the UK is irrigated, but in the eastern counties of England the proportion is more than 50%.

Blight control in France

In France, where a government initiative has set a target for 50% reduction in pesticide use by 2018, there have been trials to evaluate potato blight control to focus on this pesticide reduction goal. Products which elicit plant disease defence responses, such as potassium phosphite, an inorganic salt with fungicidal properties, and manganese products, have been evaluated in combination with reduced dose fungicide treatments for blight control. Trial results for combination treatments such as these using an elicitor product combined with 50% of the commercial fungicide dose have produced the same level of disease control as plots treated with 100 % of the commercial product.

Potato storage

In the UK about 4million tonnes of potatoes are stored after harvest; of these, about 50% are crops destined for fresh prepack markets, which are usually stored at chill temperatures to suppress sprouting without the use of chemical inputs. The remaining 50% are utilised by the processing sector, where chill storage would lead to the accumulation of reducing sugars in the tubers with an adverse effect on fry colour. In this situation sprout suppression is managed by the application of storage chemicals. The most widely used and the most effective chemical is CIPC (chlorpropham), which must be applied as a thermal fog at critical timings depending on the length of time the potatoes are to be stored. The applications are usually made by a contractor using specialist equipment. High residue levels of CIPC were detected in potatoes during monitoring, which led to the threat of withdrawal of authorisation of this widely used product. Research carried out by the Potato Council showed that the high residues were the result of poor distribution of the chemical fog, which deposited excessive amounts of CIPC on the surface layers of the stored crop and failed to effectively circulate the application throughout the store. The research showed that a more even distribution of CIPC can be achieved by manipulating the store ventilation during the application process. The outcome was that a stewardship group was formed and the 'Industry Code of Best Practice for Application of Chlorpropham Potato Sprout Suppressant' was published in 2009. Benefits of using this approach are that potatoes receive a more uniform application, sprouting is more effectively controlled, and fewer applications are needed in long term stores.

Use of beneficial insects

Insects that cause economic damage to crops have a number of natural enemies, many of which are not well known due to their small size. When integrated crop management strategies are adopted, these beneficial insects can contribute to the control of pest insect infestations by minimising their population growth. This may enable pest insects to be reduced to a level which prevents them from causing significant economic damage to the crop. Beneficial insects are effective through two principal modes of action: some behave as predators by directly feeding on the eggs, larval stages or adults of pest species, and others are parasites and complete a part of their life cycle with a detrimental effect on their host.

To be effective as beneficial insects a suitable habitat needs to be provided for their life cycle, such as hedgerows containing mixed plant species, field margin strips of wild flowers, and beetle banks consisting of grassy strips in large fields. In addition, the crop protection chemicals applied to the crop must be selected only from those products which are less harmful to natural enemies and pollinator insects. Unsprayed headlands and LERAP buffer strips will protect beneficial insects in field margins. In some situations the use of minimal cultivation will provide a better habitat for beneficial species such as ground beetles.

Inclusion of flower-rich field margins that increase levels of biodiversity on the farm provide an opportunity to combine conservation objectives with the benefit of enhanced pest control. Current stewardship options include pollen and nectar mixes targeting bees and butterflies, as well as plant selections to encourage farmland birds. Work has also shown that floristically diverse field margins can promote pest natural enemies. However, margin prescriptions targeting one objective can exclude other benefits. It is recognised that an unsuitable selection of plants in a field margin could promote certain pest insects.

The use of field margins and hedgerows to manage pest insect populations has been one of the objectives of the EU ENDURE project. Useful insights into this approach were made in a paper entitled 'Landscape studies for conservation biological control research: status and future needs. A meta-review from the European Union Network of Excellence project ENDURE'[i]. This meta-review of 90 review papers was used to assess the status of research into landscape management for conservation biological control and identify gaps in the science. Key findings included the large number of reviews identifying the need for more studies on the effect of landscape-scale interactions. While some studies show effects on populations of beneficial insects, the project identified a lack of assessment of the impacts of different landscape configurations on pest populations and on crop damage. This lack of knowledge about the effects of field margin management on crops acts as a barrier to progress. The review also found that a common approach to sampling methods would increase the value of individual studies.

There was good evidence that conservation plants in field margins result in an increase in abundance of beneficial species and biodiversity, but only weak evidence that these biocontrol strategies have an impact on pest species or contribute to a reduction in crop damage when these conservation plants are grown in the cropping area.

A follow-on project in the HORTLINK programme (HL 0192)[ii], led by Lancaster University, is identifying how field margins around vegetable crops could be encouraged to support a more diverse community of beneficial insects. Seed mixtures have been designed using 22 flowering plant species which have been identified as hosts to several kinds of beneficial insects, including bees, hoverflies and parasitoid wasps, without encouraging crop pests. Some of these are potentially valuable ‘banker plants’, which are hosts to different types of benign aphids early in the season, which can act as a food source for beneficial insects, enabling populations to build up before the pest aphids arrive. The project is using knowledge from current European biodiversity research to measure the impact of established field margins on pest populations in crops. The crops included in the trials are carrots, cabbages, peas and cereals. The trials assess the numbers of pest aphids in the crops adjacent to flower rich field margins compared to those found adjacent to grassy field margins. While farmers and growers are embracing the use of field margins to enhance biodiversity, grass mixtures are more commonly used and are easier to establish than flowering plants such as fennel, yarrow, red clover, cornflower and teasel. The work will develop a database of suitable flowering plants and beneficial insects to help growers choose the plants that best match their situation. The project is also exploring how field margins could be used in a trap-crop approach, attracting the pest from the crop to ‘trap plants’. For example, chervil and yellow mustard attract egg-laying females of pests such as cabbage root fly, but don’t provide the right conditions for the larvae to survive. Such trap plants could also be sprayed.

Beetles

There are two important groups of beetles that will provide benefits to crop production: the Rove beetles in the family Staphylinidae , and the ground beetles in the family Carabidae. The rove beetles hibernate in long grass, field margins and grassed strips known as 'beetle banks'. The adult beetles will move into a crop in spring and summer and can directly feed on aphids. In some species, the beetle larvae will parasitise the pupae of fly pests such as cabbage root fly.

The ground beetles are present in crops all the year round and will predate a range of pests such as slugs, snails, fly larvae, aphids and flea beetles. Some species seek out the eggs of several fly pest species. They are active between April and September and are most active at night.

Hover Flies

This family of insects produce larvae which are important aphid predators. Each larva is said to be capable of consuming 300 aphids before pupating. Adult populations of hoverflies are attracted by wild flower margins and flowering crops.

Ladybirds

Ladybirds are widely distributed beneficial insects which hibernate in winter as adults and are active between May and September. The eggs are laid amongst aphid infestations, both the larval and adult stage of the ladybird will feed on aphids.

Lacewings

This is another insect with a larval stage which feeds voraciously on several pest insects such as aphids, eggs of butterflies, young caterpillars and thrips.

Parasitic wasps

These wasps, members of the order Hymenoptera, are more accurately named parasitoids. The adults seek out the eggs of moths and butterflies, into which they lay their own eggs; as the larvae and pupae develop they are predated by the emerging wasp larvae at the expense of the host.

Introduction of beneficial insect

Beneficial insects such as those described above can be encouraged to inhabit crops and field margins by providing suitable habitats. However, an approach more commonly used in protected crops is to introduce colonies of beneficial insects by transferring into the crop eggs or adults of insects which have been raised in a controlled environment. The predatory mite *Phytoseiulus persimilis* is commonly introduced into glasshouse crops to control infestations of red spider mites. This approach is also effective in field crops with a large leaf canopy and a long harvest season such as stick beans. The red spider mites cause extensive damage to leaves in hot summer weather and the adults can over winter in the bamboo canes used to support the crop. By introducing *Phytoseiulus* under favourable conditions the predator mite will feed on the red spider pest and reduce crop damage to a minimum.

Trials are in progress to find a biocontrol predator insect for control of Western Flower Thrips. This pest is now widespread in protected crops, but has more recently been found in outdoor strawberries. Two predator mites *Amblyseius cucumeris* and *Orius laevitgatus* show potential.

One downside to encouraging large populations of beneficial insects by introduction or by using field margins to increase biodiversity is that this can lead to an increased incidence of larvae of these beneficial insects, such as hover flies, which if present in the crop at harvest will cause customer complaints.

Pesticide application techniques

The influence of application method on pesticide efficacy has been investigated by some pesticide manufacturers. Trials on cereal crops indicate that the angle at which the spray nozzle delivers the spray treatment will improve the deposition of the spray on the crop. By modifying the application method, the control of fungal disease is improved and crop yield is increased. Results of the trials carried out under conditions of high disease pressure suggest that if flat fan nozzles are angled forward by 30 degrees, yield could be improved by 0.24t/ha. Small yield improvements were also seen with the use of alternating forward facing and downward facing nozzles and by changing the water volume from 200l/ha to 100l/ha.

The trials also evaluated the use of low drift air inclusion nozzles; these were less effective in controlling fungal disease and did not provide a yield benefit in these trials. However, it is important to remember that not all spray applications are made in ideal conditions and the flat fan nozzles could not be used where there is a risk of spray drift. In the real world air inclusion low drift nozzles would be a practical solution in changeable conditions. The disadvantage of less effective spray deposition when using low drift nozzles can be overcome by adding an adjuvant product to the spray tank. But this approach may not be compatible with all spray formulations as some may react with the adjuvant to cause blockages in the nozzles. These trials indicate that improvement in pesticide performance is possible by manipulating the application technique, but this requires attention to detail and further product development by the manufacturers.[iii]

Conclusions

It is clear that farmers and growers are developing and applying a number of techniques to reduce pesticide usage – both by employing alternative regimes, such as physical removal of weeds and use of biocontrol agents, to more targeted and effective use of pesticides. European Community legislation has laid down a requirement to follow this route, and it is likely that further 'alternative' techniques will continue to be developed.

Richard Stanley
+44(0)1386 842004
richard.stanley@campdenbri.co.uk

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[i] Ferguson, A.W. and Alomar, O. (2010) Landscape studies for conservation biological control research: status and future needs. A meta-review from the EU NoE project ENDURE. *Bulletin IOBC/WPRS, Landscape Management for Functional Biodiversity,* 56: 41-44.

[ii] George D, Croft P, Northing P, and Wackers F. (2010) A plant-based multi-functional approach to designing perennial field margins for vegetable rotation schemes. *AAB meeting Advances in Biological Control Nov 2010*

[iii] Impey, L (2012) Boost fungicide efficiency by changing your method. *Farmers Weekly* 9 March 2012 Reed Business Information

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