Potatoes - conventional, IPM and organic systems in Europe

Many pesticides used on potatoes are associated with health and environmental hazards and their residues are often detected on shop bought samples. Developments in integrated pest management and organic systems can successfully reduce or eliminate their use. New regulatory and financial instruments are needed to encourage the growth of these production systems.

In 2002 some 6.7 million tonnes of potatoes were produced within the 25 European Union Member States on 2 million hectares of land. Forty seven percent of this land belonged to the 10 Member States (EU-10) which joined the EU in 2005, with the other 53% in the remaining 15 Member States (EU-15). The overall average yield was 28.65 tonnes per hectare (t/ha), with yields considerably higher in the EU-15 countries (37.14 t/ha) compared to the 10 new Member States (18.9 t/ha)[1].

Pesticide use

Potatoes are vulnerable to a variety of pests and diseases which conventional farming combats with a range of insecticides, fungicides, nematocides and herbicides (Table 1)[2]. Indicators of EU pesticide use on potatoes are hard to find. However, the UK government carries out regular surveys and results from their most recent survey of potato growers, carried out in 2003, are presented[3].

Great Britain

Fungicides are applied to almost all potatoes produced in Great Britain (England, Wales and Scotland) - both ware (for human consumption) and seed potatoes. In addition, 62.6% of ware and 90% of seed potato acreage is treated with insecticides. Herbicides and dessicants are used on more than 95% of the potato acreage. Sulphuric acid is applied to 21.2% of ware and 85.8% of seed potato acreage. Seed treatments are applied to 72% of ware crop acreage and 97.9% of seed potato acreage. All seed potato acreage received some sort of treatment while 0.1% ware potato acreage received no pesticide treatment.

During the vegetative phase ware potatoes are sprayed on average 14.5 times and are treated with 19.4 different products; fungicides are applied most frequently. Seed potatoes are sprayed 10.7 times with 17.5 products; again fungicides are applied most frequently.

Health hazards

Several of the pesticides used in conventional potato production in the UK are associated with serious health hazards (Table 2)[5]. Six of the most commonly used are classified as known, likely/probable or possible carcinogens (as classified by the International Agency for Research on Cancer, the United States Environmental Protection Agency and the European Union). WHO classifies oxamil as highly hazardous (group Ib) and aldicarb as extremely hazardous (group Ia). Seven pesticides have been linked to endocrine dis-

Table 1. Pesticides commonly used on potatoes in GB

	kg of active /ha	% area treated with active	no. of applications
Fungicides			
Ware potatoes			
Cymoxanil/maneb	1.415	27	4.12
Fluazinam	0.133	22	3.79
Cyazofamid	0.079	9	2.02
Mancozeb	1.392	6	3.62
Dimethomorph/mancozeb	1.458	6	2.11
Seed potatoes			
Cymoxanil/maneb	1.423	33	3.34
Fluazinam	0.144	15	3.00
Cymoxanil	0.072	12	2.85
Cyazofamid	0.078	7	2.00
Dimethomorph/mancozeb	1.479	5	1.50
Herbicides			
Ware potato			
Linuron	1.170	24	1.00
Diquat/paraquat	0.461	22	1.03
Diquat	0.446	18	1.40
Glyphosate	1.091	8	1.02
Metribuzin	0.588	6	1.18
Seed potato			
Linuron	1.020	36	1.00
Paraquat	0.511	22	1.00
Diquat/paraquat	0.459	21	1.00
Diquat	0.400	11	1.76
Metribuzin	0.577	9	1.15
Insecticides			
Ware potato			
Pirimicarb	0.115	44	1.34
Lambda-cyhalothrin	0.007	23	1.62
Pymetrozine	0.103	13	1.51
Oxamyl	4.453	7	1.00
Aldicarb	1.449	6	1.00
Seed potato			
Lambda-cyhalothrin	0.006	34	2.58
Pirimicarb	0.108	23	2.33
Deltamethrin/pirimicarb	0.088	12	1.83
Pymetrozine	0.122	12	1.32
Lambda-cyhalothrin/pirimicarb	0.120	12	2.67

Table 2. Hazards of pesticides used in potato production

Active ingredient	Acute toxicity*	Carcinogenic	EDC, Dev/rep toxin	Groundwater Contam	Cholinesterase Inhibitor
Fluazinam (f)	Not listed	Possible	Not listed	Insuff Data	No
Maneb (f)	U	Probable	Susp EDC	Insuff Data	No
Cymoxanil (f)	III	Not Likely	Not listed	Insuff Data	No
Mancozeb (f)	U	Probable	Susp EDC	Insuff Data	No
Dimethomorph (f)	U	Not Likely	Not listed	Insuff Data	No
Imazalil (f)	II	Likely	Dev/rep toxin	Insuff Data	No
Pencycuron (f)	U	Not listed	Not listed	Insuff Data	No
Linuron (h)	U	Possible	Susp EDC Dev/rep toxin	Potential	No
Paraquat dichloride (h)	II	Not likely	Not listed	Potential	No
Diquat dibromide (h)	Not listed	Not likely	Not listed	Potential	No
Glyphosate (h)	U	Not likely	Not listed	Insuff data	No
Metribuzin (h)	II	Unclassifiable	Susp EDC Dev/rep toxin	Potential	No
Pirimicarb (i)	II	Not listed	Not listed	Insuff data	Not listed
Lambda-cyhalotrin (i)	II	Unclassifiable	Susp EDC	Insuff data	No
Pymetrozine (i)	Not listed	Likely	Not listed	Potential	Not listed
Oxamyl (i,n)	Ib	Not likely	Not listed	Insuff data	Yes
Aldicarb (i)	Ia	Unclassifiable	EDC	Yes	suspected
Deltamethrin (i)	II	Unclassifiable	Not listed	Insuff data	No
Pirimicarb (i)	II	Not listed	Not listed	Insuff data	Yes

** The World Health Organization classifies pesticides into four groups: Class Ia Extremely Hazardous, Class Ib Highly Hazardous, Class II Moderately Hazardous, Class III Slightly Hazardous, U Unlikely to present hazard in normal use*
i - insecticide; f - fungicide; h - herbicide; n - nematicide

rupting effects and/or act as developmental or reproductive toxins. Six chemicals are thought to be ground water contaminants.

Pesticide Reduction

Conventionally grown potatoes are one of the crops in which pesticide residues are most frequently detected in the UK and Europe[4]. Many of these pesticides are associated with serious health or environmental impacts potentially posing a threat to consumers and the environment. Consumers are aware of these hazards and are concerned about pesticide residues in food.

Integrated pest management

Pesticide reduction is technically achievable by adopting an integrated approach to pest management.

PAN Europe has defined key elements for general integrated pest management (IPM) standards which should minimally be[6]:

- a soil structure serving as an adequate buffering system for agriculture
- a crop rotation frequency enhancing a balanced population of soil organisms, preventing outbreak of soil-borne pests
- use of the best available pest-resistant (non-GMO) crop varieties
- optimal crop distance and crop management to prevent growth of fungi
- availability of refuges for natural enemies of pests and for the prevention of pesticide-resistant pests
- economical nutrient management based on information about nutrients already present in the soil and about the soil structure, and application only on the crop
- in principle only mechanical weeding (or other non-chemical methods such as the use of heat); only exception in the case of bad weather conditions
- use of pesticides based on information on the presence of pests (scouting, traps, on-line forecasting services) and only the use of selective (not harmful to beneficial organisms) pesticides which are not persistent, bio-accumulative or toxic
- priority is given to the use of 'green' (non-synthetic) pesticides and pest-preventive substances
- minimal input of material resources

These general standards would translate into a set of minimum standards for each crop. Key elements of an IPM standard for ware potatoes are presented in Box 1[7].

In addition to these basic elements, a good disease forecasting system can significantly decrease fungicide usage. Six different decision support systems exist to control late blight: Simphyt, Plant-Plus, NegFry, ProPhy, Guntz-Divoux/Milsol and PhytoPre+2000. Use of these decision tools has been documented to reduce fungicide input by 8-62%[8]. Biological agents can be used to control or prevent fungal diseases. Oils originating from garlic, peppermint, rosemary and thyme may reduce potato storage diseases and in some cases increase yields by about 30%[9]. New methods for potato foliage control before harvest such as steam defoliation via a commercial

Box 1. Key elements of an IPM system for ware potatoes

Soil structure	Minimum clay % and humus %
Crop rotation	One in 4; longer rotations wanted in future (1:6) Analysis of nematodes on 25% of surface area per year
Varieties	Priority to late blight resistance and early potato varieties Nematode resistance
Fungal disease management	A low number of plants grown per metre Working remnants of former crop under the soil
Refugia	2% of surface area under wild herbs/flowers; could coincide with the non-spraying/nutrient zone Maintaining and creating hedges and grassy banks
Nutrient management	In winter, sow green catch crop Nitrogen-loss must be < 200 kg/ha; in two years lowered to 150 kg/ha. If P_2O_5 concentration > 60 kg/ha, no use of P-fertiliser; if P_2O_5 concentration < 60 kg/ha, maximum P_2O_5 loss 35 kg/ha
Weeding	Mechanical weeding before and during the crop season; exemption only in bad weather with written authorisation of the certifying organisation
Pesticide use	Use of *Phytopthora* alert system Maximum use of 10 kg/ha of active ingredient; in two years lowered to 8 kg/ha
Non-chemical pesticides	Use of plant reinforcing substances, bentonite, citrex
Resource management	No use of groundwater as water supply

steam weeder, instead of using harmful desiccants like sulphuric acid, could reduce herbicide use[10].

Many different crop specific IPM guidelines exist in Europe. A consortium between Wageningen University, Laurus supermarket and a group of progressive farmers in the Netherlands has developed detailed guidelines for potato production[11]. In addition, the International Organisation for Biological and Integrated Control of Noxious Animals and Plants (IOBC) has published detailed crop specific Integrated Production guidelines for field grown vegetables including potatoes[12]. Both of these guidelines are summarised in an extended version of this factsheet which is available online[13].

There is a need to adopt pesticide reduction throughout the food chain, starting with appropriate support for farmers and ending with a good level of information for the final consumer. An example of this type of 'food chain' approach is the self-certification scheme started by Legambiente (the largest Italian environmental organisation) to grow and market products without pesticide residues. A further example is the collaboration between the World Wide Fund for Nature (WWF), the Wisconsin Potato and Vegetable Growers Association and the University of Wisconsin to promote the development and industry-wide adoption of pesticide reduction. Both these examples started as a response to a consumer demand for environmentally responsible produce.

In the Legambiente scheme, the production of potatoes is based on Integrated Pest Management guidelines approved for use in the region, supplemented with further restrictions in terms of number and timing of sprays. Farmers are part of agriculture cooperatives with their own advisory system, and in addition, Legambiente outsourced the technical support to an independent consulting firm. Produce is priced slightly above the conventionally grown potatoes but consumers seem willing to pay this slightly higher price for a product that guarantees no pesticide residues[14].

In the Wisconsin scheme, the collaboration started by setting goals for pesticide risk reduction and for 'bio- Integrated Pest Management' adoption. A set of eco-potato standards was set and a not-for-profit association established to certify growers. One success of the programme is reflected in the reduced use of toxic products. To qualify for the eco-label, growers have to eliminate the use of 12 specific pesticides and cannot exceed certain quantities of other highly hazardous pesticides defined on the basis of their acute and chronic toxicity, ecotoxicity, the impact on beneficial organisms and resistance management. Prices are set between those of conventional and organically grown potatoes, to give farmers a fair return for high quality produce in a healthy environment[15].

Within the EU, all farmers may be required to adopt IPM practices in the near future. According to the new Framework Directive to achieve a Sustainable Use of Pesticides (COM (2006) 373), adopted recently by the European Commission, general IPM standards should be adopted by all farmers from January 2014 onwards. However, crop specific standards will unfortunately only be adopted on a voluntary basis[16]. This means that the level of detail required for these measures to be effective will be lost.

PAN Europe is calling for crop-specific standards to be established at a national level and applied on a compulsory basis, following a set of key elements. This should be accompanied by adequate advice and training for farmers provided by an independent advisory system and funded by a pesticide levy.

Organic production

Many farmers go a step further than IPM by growing potatoes organically. Data from different countries is hard to compare and the production and yield of organic versus conventional potatoes is only available in a few cases. For example, in Sweden the total production of ware potatoes from areas with subsidies for organic farming is estimated at 12,600 tonnes, almost 2% of the total ware potato production. The yield per hectare for organic potatoes was 46% of the yield achieved by non-organic methods[17].

In a study of organic potato production in seven different European countries (Table 3) Germany had the largest area planted with organic potatoes while the Netherlands had the largest percentage of land growing organic crops planted with potatoes, 15%[18]. Switzerland had the highest percentage of their overall potato harvest which was grown organically.

In spite of lower yields of organic potatoes, gross margins were two to three times higher than that for conventional potatoes in UK and Germany (Table 4). In Poland, the profits from organic farming depended on the premiums available. Costs for organic potato production were equivalent or lower in the UK and Poland. In Germany, costs of production are generally higher than for conventional. The prices of early organic and organic potatoes for processing are approximately three time higher than the price of the conventional potatoes in both UK and Germany[19,20].

Organic standards

The EU Council Regulation on organic agriculture (EEC) No.2092/91 has been introduced to ensure the authenticity of organic farming methods and the quality of organic products. It describes permissible practices and inputs, and regulates labelling, processing, marketing and inspection of organic products[21]. A Compendium of UK organic standards which is based on, and complies with, Council Regulation (EEC) No. 2092/91(as

Table 3. Organic potato production in Europe, 1998-2000

	area under organic potato (ha)	organic potatoes as % of total organic	organic potatoes as % of total potatoes	% increase in acreage under organic potatoes
Denmark	755	1.95	2.10	146
France	579	1.61	0.35	120
Germany	4700	3.36	1.58	111
Netherlands	749	15.14	0.59	130
Norway	125	11.96	0.74	189
Switzerland	500	11.45	3.61	113
United Kingdom	911	11.05	0.55	154

Table 4. Comparison of conventional and organic potato production, Germany, UK and Poland.

	Yield (t/ha)	Variable costs (€/t)	Gross margin (€/ha)
United Kingdom			
Conventional for processing – East Anglia	42.5	3446	2138
Conventional earlies – SW England	22.5	2461	2525
Organic	25.0	3037	7225
Germany			
Conventional for processing – Brunswick	41.9	1580	2275
Conventional earlies – North-west coast	27.2	2001	2813
Organic for processing – Brunswick	25.1	1645	5052
Organic earlies – Brunswick	16.3	2556	5816
Poland			
Best conventional farms intensive	44.7	1703	1077
Best conventional farms ICM	24.5	912	281
Best organic farms	21.0	821	180 (no premium) 788 (with premium)

amended) sets out standards for organic food production in the UK[22]. Some member countries have published additional standards. Furthermore, there are private standards for organic farming published by certification bodies (such as, Naturland, Bioland, Soil Association) which set even higher standards for organic farming in many countries.

Marketing

Prices of organic potatoes in conventional markets vary due to intense competition from conventionally grown potatoes, variable production costs, and government subsidies. To keep production profitable in conventional wholesale or packing markets, organic potato growers have to maintain high saleable yields of high quality, which is not always possible. Moreover, there are no established large-scale local markets for organic potatoes. Consequently, organic growers tend to sell their products in niche markets, market stalls or farm shops[23]. In many countries policies have been introduced to encourage organic farming, such as area targets, conversion subsidies, organic maintenance payments, support for marketing and distribution, reduced interest rates (such as 'Green Financing' in the Netherlands) and support for extension, research and education. A new potential instrument to stimulate organic agriculture is to eliminate or reduce Value Added Tax (VAT) on organic products, while maintaining VAT on non-organic food products. This would reduce the price of organic food for consumers and lead to higher prices for farmers[24].

Organic potato production is very small in Europe. Although it is steadily growing, it is unlikely that significant numbers of conventional farms will convert to organic in the near future. Although many countries have introduced policies beyond the EU framework for organic agriculture (Council Regulation (EEC) No 2092/91) to encourage organic farming such as 'Green Financing' in the Netherlands, new financial and fiscal instruments still need to be introduced.

Non-chemical pest management

Potatoes are vulnerable to a range of pests, the most significant of which are the Colorado potato beetle, aphids (hosts to viruses which attack potatoes), wireworms, white grubs, cutworks, potato flea beetle and nematodes. Information on non-chemical management of the Colorado potato beetle is given below. Information on managing the other pests can be found in the expanded factsheet available online[25].

Colorado potato beetle

Colorado potato beetle (CPB; *Leptinotarsa decemlineata*) is one of the most widespread and destructive potato pests. It feeds on leaves and if left uncontrolled can completely defoliate plants, resulting in reduced tuber size or plant death. It is difficult to control without insecticides. However, the population of CPB can be reduced:

- Isolate field from areas planted previously
- Rotate crops (excluding plants in same family - tomato, pepper, aubergine)[26]
- Flame between potato emergence and 25cm height when the plant is most tolerant[27]
- Line trenches with plastic to block CPB[28]
- Use a field-edge trap to prevent overwintering pests from entering fields[29]
- Mulching with wheat or rye straw may reduce CPB ability to locate potato fields. The mulch also creates a microenvironment that favours CPB predators[30]
- Plant early-maturing varieties that develop tubers before CPB spreads.

CPB has several natural enemies, predators and parasites. Ladybirds, lacewings, predatory stink bugs and spiders are predators. *Doryphorophaga doryphorae* and *D. coberrans* are two species of fly that parasitize CPB larvae. *Edovum puttleri*, is a wasp that parasitizes eggs. Nematodes of the *Heterorhabditis* and *Steinernema* genera are parasitic to CPB[31]. Only a few of these are produced for commercial use. However, a spray produced from *Bacillus thuringiensis* var. *tenebrionis* (*Bt*), is effective against both adult and larval stages of CPB. The fungus *Beauveria bassiana* is also effective.

Non-chemical disease management

Adopting good phytosanitary measures that reduce or minimise the sources of fungal or bacterial spores (inoculum) are essential. These include:

- Using disease-free tubers
- Destroying crop residues
- Eliminating cull piles
- Eliminating volunteers
- Considering prevailing wind directions
- Removing potato plant foliage (dehaulming) before harvest (2 weeks)
- Rotation with non-host species (tomatoes, peppers, aubergines are in the same family and are hosts for the same diseases)
- Growing resistant cultivars
- Using low-generation certified seed
- Using whole seed to reduce the risk of spreading disease during cutting
- Isolation of crops
- Choosing cooler sites to minimise spore formation
- Choosing early maturing varieties
- Adjusting crop density to reduce humidity
- Using local forecasting techniques and models (such as Blight-Mop)
- Daily monitoring
- Using efficient spraying equipment
- Proper storage and removal of diseased tubers during packing
- Using drip instead of overhead irrigation
- Using the Smith period to identify periods of high risk of late blight spread[32]

Late blight

Late blight (*Phytophthora infestans*) is one of the most damaging diseases and can spread quickly in favourable conditions. It is the main cause of the large variation in yield between years. Fungicides based on copper have been the most effective control and organic potato production has relied heavily on their use. However, from 1 January 2006 EU regulations limited the use of copper on organic farms to 6 kg per hectare per year. Further reductions are expected[33]. Finding strategies to minimize damage from late blight without copper is now a major priority[34]. Among the many initiatives is the Global Initiative on Late Blight (GILB), a network of researchers, technology developers and extension agents who facilitate exchange of information and ideas to improve management of potato late blight in developing countries[35]. In Europe, EUCABLIGHT (Potato Late Blight Network For Europe), is a European Commission project network funded under the 5th Framework Programme[36]. A number of other networks exists[37].

Use of resistant varieties

Growing varieties with resistance to the most important diseases and pests is key to successful organic potato production. Many organisations and institutions throughout the world are developing varieties resistant to disease (particularly late blight) that can be grown organically without pesticide inputs. The blight resistance breeding program is ongoing because the late blight fungus constantly develops mechanisms to overcome the resistance and even horizontal resistance will eventually break down[38]. One of the most important varieties with good resistance to late blight originated in Hungary and is called Sarpo. It has very high foliar blight resistance. The Eve Balfour and Lady Balfour varieties bred at the Scottish Crop Research Institute are suitable for organic production as they only develop blight slowly[39]. Cara, Cosmos, Valor and Jutlandia were developed from trials conducted in the UK by the National Institute for Agricultural Botany in 1998/99 and are recommended for organic potato growers[40]. A number of research programmes have developed varieties resistant to other pests or diseases[41,42,43,44]. A summary of resistant varieties is available online[45].

Non-chemical weed management

Potatoes compete well with most weeds and can be grown without herbicides providing soil is well maintained. If soil is sufficiently moist, most weeds can be removed mechanically by cultivation, before the potatoes emerge. Weeds exert the most impact on potato growth between two and four weeks after crop emergence and so must be controlled at that time to prevent loss of yield[46]. Once potato tops have met between the rows, forming a complete foliage layer, no further weed control will be possible. If weeds have been well managed up to this stage any further weeds will be suppressed by the potato tops. Weeds can be controlled by

- Post-planting cultivation (hilling and harrowing) to control annual weeds
- Removing weeds while they are young
- Choosing fields without major weed problems
- Flaming weed seedlings before potatoes emerge
- Controlling weeds mechanically just before tops meet between rows
- Limited hand weeding of large invasive weeds such as fat hen (*Chenopodium album*), cleavers (*Galium* spp.), redshank (*Polygonum persicaria*), knotgrass (*Polygonim aviculare*) or large docks (*Rumex* spp.). Green (or hairy) nightshade (*Solanum physalifolium*) must be managed as it is very susceptible to late blight and can transmit potato viruses. Mechanical management of this weed will cut stems which can then develop roots if they are left in contact with the soil. A crop rotation including cereals or perennial grasses is the best way to manage green nightshade[47].

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This factsheet was prepared by Sanja Treskic.