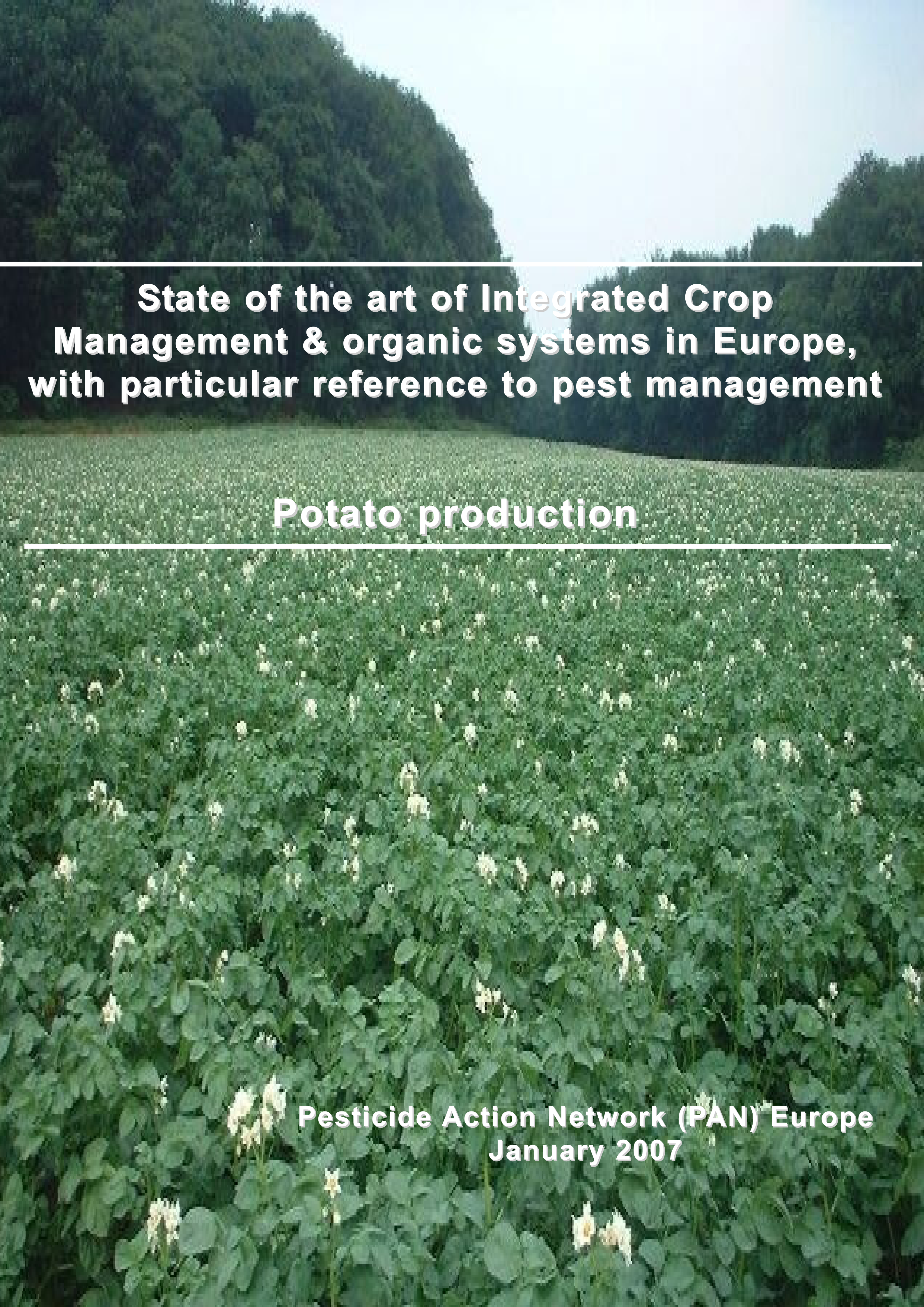

State of the art of Integrated Crop Management & organic systems in Europe, with particular reference to pest management

Potato production

Pesticide Action Network (PAN) Europe
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Potato production

Intensive conventional farming, which includes pesticide, chemical fertilisers and growth regulators application, use of heavy machinery and monoculture aims to maximize crop yield. Nonetheless, it is a dominant cause of biodiversity decline and environmental pollution. Pesticide usage and pesticide residues damage wildlife resulting in a declining number of natural enemies; heavy machinery damages soil structure and monoculture cropping leads to the deterioration of nutrition levels with a corollary of pests outbreaks. There is a growing concern among consumers about the health effects of growing (multiple) pesticide residues in food (1), hence the increasing demand for organically produced food and raising interest among producers to convert their production to organic.

Organic potato producers face some difficulties in terms of dealing with adequate plant nutrients, especially nitrogen application; weed, insect and disease control issues; profitability and marketing issues, among others. Regarding pest management, several non-chemical techniques are used for pest control, including: selection of resistant and tolerant varieties, crop rotation, destroying crop debris, biological control. Crop management includes careful timing of planting and harvest in order to avoid pests, controlled irrigation, understanding pest life cycles and all the circumstances that may influence the plant vitality to prevent damage and forecast threshold levels.

This review focuses on experiences of organic potato production in different European countries, common pests and diseases in potato production and chemical vs non-chemical pest control methods. A briefing is also available at: http://www.pan-europe.info/publications/index.htm).

I. SOME INDICATIONS OF CONVENTIONAL PRODUCTION AND PESTICIDE USE

According to Eurostat, production of potatoes in the 25 EU Member States in 2002 was 6.7 million tons, with an agricultural area of 2 million hectares. The 10 new Member States made up 47% of this area. The average yield was 28.65t/ha, with an average yield of 37.14 t/ha in EU-15 countries vs an average yield of 18.9 t/ha in the 10 new Member States. Yields higher than 40t/ha were recorded in some Western European countries: Belgium, Denmark, Germany, Spain (La Rioja), France, the Netherlands, Ireland, Switzerland and the United Kingdom (2), while most Eastern and Southern European countries have an extensive production engaging relatively large areas under potato production with rather low yield harvested. The following countries have an average potato yield 16.8 t/ha and are well below the 25 EU average: Albania, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Iceland, Latvia, Republic of Moldova, Lithuania, Former Yugoslav Republic of Macedonia, Portugal, Romania, Russian Federation, Serbia and Montenegro, Slovakia and Ukraine (3).

The largest areas under potato production as a proportion of utilised agricultural area are in regions of Belgium, the Netherlands and Poland, with more that 5% of the area under potato production. Areas in Portugal, Northern Spain, Bulgaria, Romania, Estonia, Latvia, Lithuania and England rank between 2.5 and 5% of the area under potato production (2).

Indicators of conventional use of pesticide in potatoes are difficult to find in the scientific literature. We opted to provide one complete and detailed case study on the national level (for the UK) that might illustrate the current situation in conventional potation production in Europe. The data originates from a survey about the overall use, extent and quantities of pesticide formulation and active ingredients used in arable crops in all regions of Great Britain carried out by the Department for Environment, Food and Rural Affairs and The Scottish Executive Environment and Rural Affairs Department (4).

Pesticide use in potatoes in Great Britain in 2004

All potato production in Great Britain - both ware (grown for human consumption) and seed - is grown with application of fungicides. 62.6% of ware and 90% of seed potato area were treated with insecticides. Herbicides are used in more than 95% of the fields under seed and ware potatoes. 72% area of ware crop and 97.9% of seed potato received seed treatments. Only 0.1% ware and seed potato area received no pesticide treatments.

Table 1 - Percentage of area under potatoes treated with pesticides in Great Britain

Chemical group	Ware potatoes	Seed potatoes
Insecticides	62.6	90.0
Fungicides	100.0	100.0
Herbicides & des-iccants	95.9	98.6
Sulphuric acid	21.2	85.7
Growth regulators	11.9	0.0
Molluscicides & repellents	29.1	25.1
Seed treatments	72.0	97.9
Not treated	0.1	0.0

During the vegetative phase ware potato receives 14.5 spray rounds of all pesticides and is treated with 19.4 different products. The biggest portion of those treatments accounts for fungicide spray. 10.7 spray rounds and 17.5 products are applied in seed potatoes, with highest percent of fungicides used.

Most commonly used fungicides

As for the five most commonly used fungicides, they are applied mostly for the control of late blight (Phytophthora infestans). Fluazinam is also effective against white mold (Sclerotinia sclerotiorum). Dimethomorph is also used to control rot.

Table 2 - Most commonly used fungicides in ware and seed potato in Great Britain

	Kg of a.i./ha	Proportion of area treated with a.i.	Average number of applications
Ware potatoes			
Cymoxanil/ maneb	1.415	0.27	4.12
Fluazinam	0.133	0.22	3.79
Cyazofamid	0.079	0.09	2.02
Mancozeb	1.392	0.06	3.62
Dimethomorph/ mancozeb	1.458	0.06	2.11
Seed potatoes			
Cymoxanil/ maneb	1.423	0.33	3.34
Fluazinam	0.144	0.15	3.00
Cymoxanil	0.072	.012	2.85
Cyazofamid	0.078	0.07	2.00
Dimethomorph/ mancozeb	1.479	0.05	1.50

Most commonly used herbicides

Among the five most commonly used herbicides in Great Britain, linuron is thought to be carcinogen, endocrine disruptor, developmental and reproductive toxin and ground water contaminant. Also according to PAN Pesticides Database (http://www.pesticideinfo.org), metribuzin is developmental and reproductive toxin, cholinesterase inhibitor and potential ground water contaminant and paraquat is acutely toxic.

Table 3 – Most commonly used herbicides in ware and seed potato in Great Britain

	Kg of a.i./ha	Proportion of area treated with a.i.	Average number of applications
Ware potatoes			
Linuron	1.17	0.24	1.00
Diquat/paraquat	0.46	0.22	1.03
Diquat	0.44	0.18	1.40
Glyphosate	1.09	0.08	1.02
Metribuzin	0.58	0.06	1.18
Seed potatoes			
Linuron	10.20	0.36	1.00
Paraquat	0.511	0.22	1.00
Diquat/paraquat	0.46	0.21	1.00
Diquat	0.40	0.11	1.76
Metribuzin	0.57	0.09	1.15

Most commonly used insecticides

Although widely used, aldicarb is a extremely toxic nerve poison. The acute toxicity of aldicarb is one of the highest of currently used pesticides. It is classified by the World Health Organisation as a extremely hazardous (Ia group). Oxamil is listed as a highly hazardous pesticide (Ib) and with pirimicarb acts as a cholinesterase inhibitor. Pymetrozine is believed to have carcinogenic effects.

Table 4 – Most commonly used insecticides in ware and seed potato production in Great Britain

	Kg of a.i./ha	Proportion of area treated with a.i.	Average number of applications
Ware potatoes			
Pirimicarb	8.24	0.44	1.34
Lambda-cychalotrin	266	0.23	1.62
Pymetrozine	2.18	.013	1.51
Oxamyl	51.41	0.07	1.00
Aldicarb	13.30	0.06	1.00
Seed potatoes			
Lambda-cychalotrin	0.006	0.34	2.58
Pirimicarb	0.11	0.23	2.33
Deltamethrin/pirimicarb	0.09	0.12	1.83
Pymetrozine	0.12	0.12	1.32
Lambda-cychalotrin/ pirimicarb	0.12	0.12	2.67

Pesticides used in conventional potato production in the UK have serious health hazards: 7 most commonly used pesticides in Great Britain are classified as carcinogenic. WTO classifies oxamil as highly hazardous (Ib group) and aldicarb as extremely hazardous (Ia group). Seven pesticides have been linked to endocrine disrupting effects and/or to act as a developmental or reproductive toxin. Six chemicals are considered ground water contaminants.

Residues of pesticides in conventioanally grown food are also a serious threat to consumers. Conventionally grown potatoes are among the worst crops in terms of pesticides residues in the UK and other European countries (1) (6).

Table 5 – Hazards associated with the most commonly used pesticides in potato production according to several EU and International classifications

Active ingredient	WHO	Acute toxicity	Carcinogenic	Endocrine disruptor, developmental/reproductive toxin	Groundwater contaminant	Cholinesterase inhibitor
Fluazinam (fungicide)	Not listed	?	Possible	Not listed	Insufficient data	No
Maneb (fungicide	U	No	Yes	Suspected	Insufficient data	No
Cymoxanil (fungicide)	III	Slight	Not likely	Not listed	Insufficient data	No
Mancozeb (fungicide)	U	No	Yes			
Dimethomorph (fungicide)	U	Slight	Not likely	Not listed	Insufficient data	No
Imazalil (fungicide)	II	Moderate	Likely	Developmental and reproductive toxin	Insufficient data	No
Pencycuron (fungicide)	U	No	Not listed	Not listed	Insufficient data	No
Linuron (herbicide)	U	Slight	Possible	Suspected Endocrine disruptor, Developmental and reproductive toxin	Potential	No
Paraquat dichloride (herbicide)	II	Moderate	Not likely	Not listed	Potential	No
Diquat dibromide (herbicide)	Not listed	Moderate	Not likely	Not listed	Potential	No
Glyphosate (herbicide)	U	Slight	Not likely	Not listed	Insufficient data	No
Metribuzin (herbicide)	II	Moderate	Unclassifiable	Yes	Potential	No
Pirimicarb (insecticide)	II	Moderate	Not listed	Not listed	Insufficient data	Not listed
Lambda-cychalotrin (insecticide)	II	Moderate	Unclassifiable	Suspected endocrine disruptor	Insifficient data	No
Pymetrozine (insecticide)	Not listed	Slight	Likely	Not listed	Potential	Not listed
Oxamyl (Insecticide, Nematicide	Ib	Highly	Likely	Not listed	Insufficient data	Yes
Aldicarb (insecticide)	Ia	Extremely	Unclassifiable	Endocrine disruptor	Yes	Suspected
Deltamethrin (insecticide)	II	Moderate	Unclassifiable	Not listed	Insufficient data	No

WHO classification – The World Health Organization Recommended Classification of Pesticide by Hazard classifies all pesticide into four groups: Class Ia Extremely Hazardous, Class Ib Highly Hazardous, Class II Moderately Hazardous and Class III Slightly Hazardous (The classification is based primarily on the acute oral and dermal toxicity to the rat indicated by LD50 value, a statistical estimate of the number of mg of toxicant per kg of bodyweight required to kill 50% of a large population of rats). Source: (5)

II. SCALE OF ORGANIC PRODUCTION AND COMPARISON OF YIELD AND INCOME

There is a lack of comparable data of different countries because national statistics differ and the distinction between conventional and organic farming is not always clear.

The production and yield of organic in comparison with conventional potato production is not available except for a few countries. In Sweden, for example, the total production of table potatoes from areas with subsidies for organic farming is estimated at 12,600 tons. This is almost two per cent of the total production of ware potatoes. The potato yield per hectare is almost half (46 per cent) for the organic farming compared to the non-organic farming. The results are based on a mail survey with a sample of 209 out of about 950 holdings with table potatoes registered for organic farming subsidies (7).

When comparing the area used for organic potato in seven European countries, Germany is the country with the largest area under organic potato, however the portion in total organic production as well as in total potato production is considerably small. About 15% of all organic crops are under organic potato production in the Netherlands. Switzerland has the highest percent of organic potato in potato production.

Despite the lower yields and the small percentage of organic potato production in comparison with conventional, the gross margin for the farmer is far higher in organic production. Data from Germany and the UK, compiled in Table 7, indicates much higher gross margins, even if the payment for organic farming is excluded (8). The lower yields of organic potato are compensated for by higher prices and this is a key aspect of the profitability of the organic farming. Comparison between economic performance of conventional and organic potato in the UK, Germany and Poland indicates that in spite of lower yield harvested from the fields under organic potatoes, gross margins for organic production are two to three times higher that for conventional cropping in UK and Germany. In Poland the profit from organic farming greatly depends on the premiums. In Poland costs for organic potato are lower that for intensive and integrated conventional farm, in Germany costs of production are in generally higher that for conventional, whereas in the UK variable costs are somewhere in between the conventional early potato and potatoes for processing. The prices of early organic and organic potato for processing are approximately three time higher that the price of the conventional potatoes in both UK and Germany.

Costs are generally lower on organic tillage farms than on comparable conventional farms. Variable costs decline due to withdrawal of prohibited inputs but reseeding, fertility measures and higher labour inputs may reverse this tendency.

Table 6 – Area under organic potato production, percentage of organic potato in total organic and total potato production and the percentage increase of organic potato in selected European countries for the period 1998-2000

	Area under organic potato (ha)	% of organic potatoes in total organic production	% of organic potatoes in total potato production	% increase of area under organic potato production
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	0.74	189
United Kingdom	911	11.05	0.55	154

Source (8)

Table 7 – Comparison of yields and gross margin between conventional and organic potato production in Germany, UK and Poland

	Yield (t/ha)	Variable costs (€/t)	Gross margin (€/ha)
United Kingdom			
Conventional potatoes for food processing – East Anglia	42.5	3446	2138
Conventional early potatoes – South West England	22.5	2461	2525
Organic potatoes	25.0	3037	7225
Germany			
Conventional potatoes for processing - Brunswick	41.9	1580	2275
Conventional early potatoes – North-west coastal area	27.2	2001	2813
Organic potatoes for processing - Brunswick	25.1	1645	5052
Organic early potatoes - Brunswick	16.3	2556	5816
Poland			
Best conventional farms intensive	44.7	1703	1077
Best conventional farms integrated crop management	24.5	912	281
Best organic farms	21.0	821	180 (without organic premium) 788 (with organic premium)

Source: (9), (10)

III. HOW INSECT PESTS ARE MANAGED

Producers of organic potatoes use alternative approaches rather than artificial fertilizers and pesticides. These include: crop rotation, selecting resistant cultivars, good soil management, planting disease-free seed, non-chemical weed control, usage of blight warnings and decision support systems, correct storage, among other techniques. All these methods can and are normally used in Integrated Crop Management systems and are effective to reduce pesticide use. But while in organic production there are precise guidelines limiting the number of pesticide active substances that can be used and number of applications, in Integrated Crop and Pest Management systems the guidelines and the degree of implementation of those guidelines varies between countries and regions.

Overall plant-health considerations

• It is recommended that organic potatoes be grown in a minimum of a 4-year rotation to minimize yield losses from soil-borne diseases such as Rhizoctonia, Fusarium and Verticillium.

• General soil fertility is maintained by a well-planned management system involving rotations, legumes, straw and composted manure.

• Whole seed ought to be planted for the whole uncut seed tubers are less likely to become infected with soil borne diseases than cut seed pieces.

• Vigorously growing potato plants are more resistant to insects and diseases than plants under stress. Adequate soil moisture in the presence of adequate plant nutrition will assist in maintaining overall plant health.

• Potatoes should be planted after risk of frost has passed and when rapid emergence will reduce risks of seed decay.

Most important pests that cause significant damage to potato

Colorado potato beetle (CPB)

Colorado potato beetle (*Leptinotarsa decemlineata*) is one of the most widespread and destructive potato pests. It feeds on the foliage of potatoes and if left uncontrolled it can completely defoliate potato plants, resulting in reduced tuber size or plant death. CPB is difficult to control without insecticide usage. However, some non-chemical measures can be taken to reduce the population of Colorado potato beetle:

• Isolating the field from areas where potatoes were planted in previous seasons;

Colorado potato beetle (*Leptinotarsa decemlineata*)

• Crop rotation (excluding tomato, camsicum and potato family plants) reduces and delays Colorado potato beetle population build-up (11);

• Flaming can control overwinter CPB if applied between potato emergence and 25cm in height when the plant is at the most tolerant phase(12).

• Using plastic-lined trenches as a barrier to CPBs entering a potato field (13).

• Canadian researchers have developed a portable field-edge trap to prevent overwintering pests from entering potato (14).

• Some researches has shown that mulching with wheat or rye straw may reduce CPB ability to locate potato fields, and the mulch creates a microenvironment that favours CPB predators. (15)

• In areas where CPB is a serious threat to potato crops the priority should be given to the early-maturing varieties that develop potato tubers before the pest population spreads throughout the field.

CPB has several natural enemies, predators and parasites. As examples of **predators** we have ladybirds, lacewings, predatory stink bugs and spiders. As examples of **parasites** we have *Doryphorophaga doryphorae* and *D. coberrans*, two species of fly that parasitize CPB larvae; a wasp, *Edovum puttleri*, parasitizes eggs, and two parasitic nematodes *Heterorhabditis* species and *Steinernema* species (16). However, only a few are produced for the commercial use, such as *Bacillus thuringiensis var tenebrionis* (Bt), a biological insecticides against potato beetle larvae and fungus *Beauveria bassiana*, effective against both adult and larvae stages. The effectiveness of these biological controls can be increased by providing pollen and nectar sources for beneficial insects along field borders or by planting insectary strips in the field.

Aphids

The most common aphids found in potato fields are: Green Peach Aphid (*Myzus persicae*); Potato Aphid (*Macrosiphum euphorbiae*); glasshouse and potato aphid (*Aulacorthium solani*); buckthorn/potato aphid (*Aphis nasturtii*); shallot aphid (*Myzus ascalonicus*); violet aphid (*Myzus ornatus*); black bead aphid (*Aphis fabae*); bulb and potato aphid (*Rhopalosiphonius latysiphon*). Aphids cause significant damage only in large numbers as a consequence of their feeding on sap. Attacked parts, especially young shoots, leaves and flowers become disordered, weak and eventually wilt. Yield losses are more severe due to virus diseases that are transmitted by some species. *Myzus persicae* is the main vector of potato leaf roll virus (PLRV) and potato virus Y (PVY). The standards of organic farming require the use of organically grown seeds in organic potato farming. Therefore, a high quality of seed potatoes (virus-free and healthy seed) is essential. Viral diseases are effectively controlled by the use of clean seed, careful removing diseased or abnormal plants, early top-killing (desiccation) and virus resistant cultivars. Controlling overwintering weeds on which aphids may be present and inspecting overwintered and imported plants in greenhouses since they are often the source of initial infestation of spring transplants is useful measure in preventing virus diseases. According to German studies, the early lifting of green crop tubers for seed production in the middle of July is an effective way to reduce virus diseases when there is a high pressure of aphids (17).
The spring migrations of the peach potato aphid and cabbage aphid into potato crops can be forecast using data from a network of special suction traps and information on winter temperatures. For example, information on aphid activity and forecasts in Great Britain can be obtained from the Rothamsted Insect Survey (18). Using these forcasts, farmers can target control measures only when needed.

Green Peach Aphid (*Myzus persicae*)

Wireworms and white grubs

(*Agriotes lineatus, A. obscurus, A. sputator*)
Wireworm larvae tunnel deeply into the tubers causing loss in quality and providing entrance for secondary pests and microorganisms, which can lead to rotting. These soil insects, primarily wireworms and white grubs, can severely damage seed pieces and tubers. Position in the rotation

Click beetle (*Agriotes lineatus*)

and length of any previous grassland are important. High wireworm populations are usually found in fields in long-term grassland and can cause severe damage in potato crops which follow grasslands. Methods to reduce wireworm populations cover:

- Pre-crop sampling to detect wireworm infestation by soil sampling or bait trapping method;
- Avoid wireworm infested fields for growing potatoes;
- Examine the mother tubers after planting of the early crop for signs of wireworm;
- Rotation with legumes including peas and beans (19);
- Earlier harvest, and as soon as tubers mature;
- Thorough soil cultivation before ridging in the autumn when wireworms are in upper layers of the soil profile (20).

Cutworms

Cutworms are caterpillars of nocturnal moths that feed on roots and stems and tunnel into tubers of potato plants, generally during dry weather. The most common in potatoes are: turnip moth (*Agrotis segetum*), large yellow underwing moth (*Noctua pronuba*), garden dart moth (*Euxoa nigricans*), silver y moth (*Autographa gamma*), rosy rustic moth (*Hydraecia micacea*), tomato moth (*Lacanobia oleracea*), angleshades moth (*Phlogophora meticulosa*), ghost swift moth (*Hepialus humuli*) and garden swift moth (*Hepialus lupulinus*). There are no measures that can prevent stem damage. If tuber damage is found the crop should be lifted promptly to limit further damage.

Large yellow underwing moth (*Noctua pronuba*)

Potato Flea Beetle

Flea beetles (*Epitrix spp., Psylloides affinis*) cause the small shot-hole damage to leaves when the plant is still small. These tiny beetles overwinter as adults and may appear in fields very early in the season and cause serious damage to young plants. Row covers could be used, but can be expensive. Crops under row covers usually produce earlier yields.

Damage in the leaves caused by potato flea beetles (*Epitrix spp.*)

Nematodes

Nematodes in potato crops are a very severe problem. To their significance as pests contributes the fact that the seed potatoes can not be sold within the UK unless grown in land free of potato cyst nematodes. The most common and troubles some nematode species in Europe are:

- Potato cyst nematodes *Globodera pillida* and *G. rostochiensis; Meloidogyne spp.*
- Needle Nematode (*Longidorus sp.*),
- Stubby Root Nematode (*Trichodorus sp.*),
- Potato Tuber Nematode (*Dytilenchus destructor*) and Stem Nematode (*Dytilenchus dipsaci*), and
- Root Lesion Nematode (*Pratylenchus penetrans*)

The population of nematodes can be reduced by growing tolerant cultivars, as well as by using other non-chemical methods:

- Green manure crops can reduce nematode populations. Sudan grass, white mustard, rapeseed and rye have an allelopathic effect on nematodes by releasing toxic compounds into soil. These compounds inhibit weeds as well (21);
- Land intended for potatoes ought to be tested for the presence of potato cyst nematode and if the land proves to be infested, organic potato should not be grown;
- Some crop rotation rules should be followed. Potatoes should not be grown on the same land in less than five years and the crops included into the rotation should be resistant to potato cyst nematodes species;
- If only a small amount of potato cyst nematodes is present, opt for the appropriate resistant varieties (22).

IV HOW DISEASES ARE MANAGED

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

• Using disease-free tubers, seeds
• Destroying crop residues
• Eliminating cull piles
• Eliminating volunteers
• Considering prevailing wind directions
• Removing potato plant foliage (dehaulming) in advance of harvest (2 weeks). The destruction of haulm before the tubers are harvested reduces the risk of spreading the viruses by aphids in seed potatoes, as well as minimizing tuber infection by blight
• Maintaining good rotation with non-host species (tomatoes, peppers, aubergines are all hosts for the same diseases)
• Growing resistant cultivars
• Using low-generation certified seed reduces the risk of seed-borne diseases
• Using whole seed reduces risk of spreading disease during cutting
• Isolation may reduce the risks from diseases such as late blight
• Choosing cooler sites to reduce the rate of spore formation
• Choosing early maturing (early bulking) varieties
• Adjusting crop density to reduce humidity in a microclimate
• Using local forecasting techniques and models (e.g. Blight-Mop)
• Using efficient spraying equipment
• Proper storage
• Drip irrigation system, the right type of water management based on water prevent occurrence of blight
• Using the Smith period to identify periods of high risk of late blight spread, (when the temperature and humidity favour blight: two consecutive 24-hour periods in which the minimum temperature is 10 C or above and in each of which there are at least 11 hours with a relative humidity above 90 percent)

Late blight

Late blight (*Phytophthora infestans*) is one of the most damaging diseases with ability to spread quickly in favourable conditions. It is the major cause of the immense variation in yield between years. Fungicides based on copper have been the most effective and the organic potato production greatly relied on copper application. Nevertheless, copper is being ohased-out in organic farming in the European Union. From the 1st of January 2006 EU imposed regulations on the organic farmers to use no more than 6 kg of copper *per* hectare *per* year. Further reductions can be expected (23). Withdrawal of copper pesticides as a blight control and lack of alternatives remains the growers' main concern. Thus, the priorities should be set on finding strategies to minimize damage from late blight without the use of copper. (24)

Among the many initiatives to exchange best practices for the control of late blight is the Global Initiative on Late Blight (GILB), a network of researchers, technology developers and agricultural knowledge agents gathered with an aim to exchange ideas and opinions, and facilitates communication and access to information in order to improve management of potato late blight in developing countries (25). In Europe, EUCABLIGHT Potato Late Blight Network For Europe, is a European Commission project network funded under the 5th Framework Programme (26).

Other relevant blight networks for Europe are:

- EU-NET-ICP (European network for development of an integrated control strategy of potato late blight),
- Blightmop is a project that aims at developing a systems approach to control potato late blight that maintains yield and quality of organic potato. It involves integrated use of resistant varieties, existing agronomic strategies, alternative treatments that can replace synthetic and copper based fungicides, use of existing blight forecasting systems to optimise control treatments
- Ecopapa (the Enrichment of Potato Breeding Programs in Latin America and Europe with Resistance to Late Blight),
- Incopapa-project on "Exploitation of the genetic biodiversity of wild relatives for breeding potatoes with sustainable resistance to late blight", Funded by the European Union Program for International Cooperation (INCO).
- CEENP (The Central & Eastern European Network for Potato Research),
- EAPR.(The European Association for Potato Research)
- IHAR (The Mlochow Research Center of Poland's Plant Breeding and Acclimatization Institute)

Tackling the blight problem can be done by:

- planting early varieties-potatoes planted earlier tolerate blight infection better than those planted late
- planting healthy, blight-free seed
- selecting varieties with high blight resistance
- monitoring blight development on a daily basis
- heeding blight warnings
- removing haulms from infected plants
- harvesting the crop, once skins have set
- removing all blighted tubers during packing
- crop rotation with at least three to four years between potato growing, preferably with cereals or legumes.

Early blight

Early blight (*Alternaria solani*) can be kept under control in organic farming using a combination of strategies:

1. Plant potatoes in the dry season when the incidence of early blight is lower.
2. Avoid multiple plantings in the same area; old crops are sources of inoculum of early blight for the new

plantings. Select plots surrounded by grasslands and other non-hosts of this disease.

3. Avoid the use of overhead irrigation.
4. Use disease-free certified seed.
5. Seed-beds should be distant from old plantings. Inspect seedlings for any sign of disease and discard and destroy any that are suspected of being infected.
6. Increase the organic matter in the soil as much as possible, by using old manure and maize stalk. This will increase fertility and decrease nematodes. The use of nitrogen fixing legumes in the crop rotation scheme can also increase the fertility of the land and eliminate some of the inoculum.
7. Remove unharvested plant parts and crop debris.
8. Late maturing varieties have proved to be more resistant towards early blight (27).
9. The tuber skins should be well set at harvest and the potatoes, avoid harvesting under wet conditions.

Black scurf and stem canker

Thanatephorus cucumeris (syn. *Rhizoctonia solani*) is a seed borne disease that often causes yield losses and quality deficiency in organic potatoes. Black scurf has become a significant problem since the EU imposed the regulations that growers use only organically grown seed potato for organic potato production. Potatoes are more susceptible to *R. solani* before emergence. Planting seed tubers in warm soil and shallow seedbeds with pre-germinated seeds gives the plants a quick start and speeds the emergence of the shoots. Using certified seed free of the blak spore clusters, an adequate rotation and good volunteer control can prevent soil borne *Rhizoctonia* build up. Potatoes should be harvested as soon as the skin is set, before spore clusters are formed (28).

Common scab

Common scab is a disease whose importance is often overlooked as it causes no symptoms above ground and no or little effect on total yield. However, the main effect of the disease is lowered tuber quality. As a result of high level of common scab infection the portion of potatoes harvested that is saleable is considerable reduced. Minimising common scab involves keeping soil well drained, planting resistant varieties, and avoiding planting infected seeds. Green manure crops, such as rye, millet, and oat, have been reported to reduce the incidence of scab.

Storage diseases

Diseases which cause main losses during storage are pink rot (*Phytopthora erythoseptica*), black leg and soft rot (*Erwinia carotovora* ssp. *atroseptica*, *E. carotovora* ssp. *carotovora*), pythium leak, *Fusariums* dry rot and wilt, silver scurf (*Helmintosporium solani*), black heart, etc. Potatoes are stored successfully when the storage environment conditions (mainly temperature, humidity, oxygen and carbon dioxide concentration) are controlled and adjusted to requirements to potatoes. The disease occurrence on potato tubers whilst stored can be minimised by sorting the potatoes rigorously to exclude all infected or damages tubers, avoiding tuber damage during harvesting, storing and other operations and avoiding very susceptible varieties.

Viruses

The most economically important viruses in Europe are potato roll leaf virus, potato virus Y, potato virus X. The measures that can be applied to control viruses:

* Controlling the presence of virus in the seeds,
* Frequently cleaning hand tools while working,
* Removing infected potato plants from the field,
* Weeding in the field border,
* Controlling the population of vectors (aphids) and hosts for potato viruses (nightshades and volunteer potatoes),
* Seed-potato fields should be surrounded with crop borders that are not susceptible to the virus.

Varieties

Growing the varieties with resistance to the most important diseases and pests is one of the key factors in successful organic potato production. Many organisations and institutions through out the world are working on developing varieties that can be grown organically without pesticide inputs. Research on late blight resistant varieties suitable for organic cropping are the most intensive and of great importance as blight is a major limiting factor. The blight resistance breeding program is a continuous process because the blight fungus constantly develops the mechanisms to overcome the resistance and even the more horizontal resistance will eventually break down (29).

One of the most important groups of varieties that proved to have good resistance to late blight is called Sarpo and originates from Hungary. Research shows that this group 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 very slow blighters (30).
From National Institute for Agricultural Botany (NIAB) trials in 1998/99 the following varieties were recommended for organic potato growers: Cara, Cosmos, Valor and Jutlandia (31).

Swedish potato cultivars that are commercial varieties resistant to viruses and classified by the Nordic gene bank are:

ROSVA (NGB 3199), STINA (NGB 3228) and VETO (NGB 3256) are resistant to PVY. SEMLO (NGB 3200) are both resistant to PVY and PLRV (32).

Table 8. Potato varieties according to their resistance to different diseases

Resistance to	Resistant varieties
Early blight Alternaria solani)	Ackersegen, Agin 2792,Capella, Ewerest, Fink, Goya, Huron, Kolpashevsky, Maritta, Merrimack, Ontario, Rosa(1980), Russette, Sebago, Somerset, Varmas, Victor
Fusarium wild (Fusarium oxysporum)	Atlantic
Stem canker (Rhizoctonia solani)	Ackersegen, Amsel, Start (1966), SVP 82 1932 68, TA 11 605, TA 7 387, Torva, TP 8447
Dry rot (Fusarium spp)	Asva, Desiree, Great Scot, Oleva, Tiva, Torva
Ring rot (Clavibacter michiganensis ssp. sepedonicus)	Prof Wohltmann
Late blight on tubers (natural inoculum in field) (Phytophthora infestans)	Argyll Favourite, Aura, Black King, Bobbie Burns, Bonnie Dundee, Cara, Cardinal, Craigneil, Desiree, Early Market, Eclipse, Edinburgh Castle, Glenesk, Hunters Gold, Immune Ashleaf, Mighty Atom, Pentland Javelin, Remarka, Stirling Castle, Wilja
Late blight on foliage (natural inoculum in field) (Phytophthora infestans)	Argyll Favourite, Aura, Bonnie Dundee, Bute Blues, Cara, Crimson Beauty, Early Market, Early Rose, Eclipse, Edgecote Purple, Edinburgh Castle, Hunters Gold, Irish Cobbler, ,Kepplestone Kidney , Lumpers, Meins Early Round, Mighty Atom, Mr Bresee, Pentland Javelin, Puritan, Remarka, The Baron, Wilja, Yam

Source: (33)

Table 9. Potato varieties resistant to potato cyst nematode species

Resistance to	Resistant varieties
Globodera rostochiensis race 1,2, 3, 4 and 5	AM 76 1227, Amera, Artana, Atrela, Benol, Darwina, Dorett, Franzi, Jaerla, Karida, Loman 61 62N, Miranda, MPI 71 240 97, Optima, Padea, Palladia, Pino, Ponto
Globodera pallida race 1 and 2	Atrela, Benol, Morag, Vantage
Globodera pallida race 3	AM 78 3778, AM 78 3813, AM 80 3777, AM 81 940, AM 82 137, AM 83 1324, AM 83 307, DH 84 13 705, VE 7653, VE 843, VE 846, VE 849

Source: (19)

Table 10. Potato varieties resistant to potato cyst nematode species in the United Kingdom National List, 2002

Resistant to *Globodera rostochiensis*, pathotype Ro1: Accent, Navan, Admiral, Pentland Javelin, Amour, Pomeroy, Argos, Rathlin, Bimonda, Red Cara, Buchan, Revelino, Cabaret, Riviera, Cara, Rocket, Celine, Roscor, Dundrod, Saxon, Harborough Harvest, Sebastian, Horizon, Spey, Jamila (Atlas), Stemster, Kingston, Sunbeam, Kirrie, Tay, Maxine, Valor, Maris Piper, White Lady, Midas, Winston, Nadine
There are no cultivars on the National List with full resistance to *Globodera pallida*, pathotypes Pa1, Pa2, Pa3

Source: (20)

V HOW WEEDS ARE MANAGED

Potato competes very well with most weeds and can be grown without herbicides providing the good soil maintenance. If soil is moist enough, most weeds can be removed mechanically by cultivation, before the potatoes emerge. Weeds exert the most impact on potato growth during the first 2-4 weeks after crop emergence and it is crucial to be controlled at that time in order to prevent yield loss (34). Once the potato tops have met between the rows, forming a complete foliage layer, no further weed control will be possible. If it was well carried out before this stage any further weeds will be suppressed by the potato tops.

Weed control

- Post-plant cultivation (hilling, harrowing and hilling) is effective in controlling annual weeds, however, excessive cultivation or cultivation at the wrong time may reduce yield as a result of damaging roots, stolons or tubers
- Remove weeds while they are still at the seedling stage
- Choosing (where possible) fields with no major weed problems
- Flame weeding of weed seedlings before the potato tops emerge - this is expensive
- Mechanical weed control just before tops meet between rows
- Limited hand weeding of any large invasive weeds such as fat hen (*Chenopodium album*), cleavers (*Galium* spp.), redshank (P*olygonum persicaria*), knotgrass (*Polygonim aviculare*) or large docks (*Rumex* spp.)

It is very important to manage green nightshade weed (*Solanum physalifolium*) as it has been found to be very susceptible to late blight and can be carrying and transmitting potato virus. It is a great risk of disease inoculum to potatoes. The problem with mechanical weed management of this weed is that it has been observed to develop roots in the internodes when the stem gets in contact with the soil and it might limit the efficiency of harrowing and ridging. A crop rotation including cereals or perennial grasses will be the best way to manage green nightshade (35).

VI EXAMPLES OF BEST PRACTICES IN INTEGRATED PEST MANAGEMENT POTATO PRODUCTION

The tables below present the guidelines for best practices in potato production developed and applied by a consortium between Wageningen University, Laurus supermarket and a group of progressive farmers in the Netherlands (36).

Table 11. Hierarchy of IPM measures and coding of subtypes in potato production in Netherlands

Type of measure	Subtype
1. Prevention	1a. Healthy starting materials (plants, seeds) 1b. Hygienic measures on the farm/ field 1c. Condition/Treatment of the soil 1d. Cultivation and crop rotation 1e. Choice of crop and variety 1f. Time of planting/sowing 1g. Knowledge of diseases, pests and weeds
2. Technical measures for cultivation	2a. Scouting/crop quality damage threshold 2b. Plant distance and density 2c. Fertilizing 2d.Climate regulation in glasshouses 2e. Crop care
3. Systems for early warning and advice	3a. Use of weather systems and pests traps 3b. Decision supporting systems
4. Non-chemical crop protection	4a. Use of natural enemies of pests 4b. Mechanical/thermal foliage killing 4c. Mechanical techniques of weed killing 4d. Plant strengtheners 4e. Crop protection substances of natural origin 4f. Flooding 4g. Biological soil treatment
5. Chemical crop protection and application techniques	5a. Choice of substance 5b. Seed coating 5c. Spot application 5d. Low dosage system
6. Emission reduction	6a. Choice of substance (pesticides) 6b. Catch crop/ bigger cultivation-free zone

Table 12. Best practices recommendations for potato growers in Netherlands

IPM-measures to be implemented in potatoes growing	Coding measure subtype	Implementation grade in practice	Constraints	Contribution to lower-ing environ-mental pressure	Useful in organic cultivation	Short comments on measure
1. Chose the best resistant variety against Late Blight/*Phytopthora*	1e	1-2-3	2-3	2	1	First and for all it is important to chose the best *Phytopthora*-resistant variety. Dosing and frequency of treatment with fungicides can be reduced. Resistance against soil nematodes is also useful
2. Use of recent nematode-analysis of the soil for the choice of crop, rotation frequency and variety	1g	2-3	4	2	1	Nematodes giving root knot should be virtually absent. A wide crop rotation is the best strategy for avoiding accumulation of these nematodes. Some green plants are also capable of reducing the nematode-numbers.
3. Use of pesticides against *Rhizoctonia* on the basis of damage threshold	2a	2-3	3-4	4	2	Knowledge and use of *Rhizoctonia*-index is necessary. (Rhizoctonia is a soil-bound fungus and can give rise to stem and stolon canker)
4. Moderate fertilization with the use of stepwise dosage system	2c	2-3	2-3-4	3	1	Stepwise dosage system based on cropscan, analysis of foliage and/or analysis of minerals (N, P, K)
5. Chose the ‘environmental’ strategy in the decision supporting system (*) for *Phytopthora* management	3b	2-3	1-2-3-4-5	3	2	Instead of choosing ‘low costs’ or ‘avoiding risks’ the decision supporting equipment should be programmed on ‘environment’
6. Use of GEWIS (**)	3b	2-3	1-2-4	3	2	GEWIS is a decision supporting system reducing the use of pesticides by advising the optimal spraying moment
7. Develop and use FAB-plan	4a	4	4	3	1	Use of Functional Agro Biodiversity (like small zones with wild herbs and flowers) raises the number of natural enemies of pests
8. Use mechanical foliage killing	4b	2-3	2-3	1	1	Burning or crushing foliage substitutes chemical treatment
9. Use mechanical weed killing	4c	2-3	2-3-4	1	1	Before planting mechanical weeding should be standard; after planting special equipment can kill weed mechanically in rows and even between plants (‘finger weeders’).
10. Choice of pesticides used	5a	2-3	4	2	2	Knowledge of unwanted effects of pesticides is missing
11. Avoid pesticides which kill natural enemies of pests	5a	3	4	3	2	Knowledge and awareness is missing in the agricultural world
12. treatment of seeds against aphids	5b	2	1	3	2	Use of a pesticide while sowing prevents full field spraying

Explanation of the codes used

Coding measure subtype: See Table 11
Implementation grade in practice: 1= used generally, 2 = use on front-running farms, 3 = use on experimental farms, 4 = strategy in development
Constraints: 1 = costs, 2 = labor, 3 = risks, 4 = risk perception, 5 = no authorization
Contribution to lowering environmental pressure: 1 = creating independence of chemicals, 2 = big, 3 = medium, 4 = small, 5 = no contribution
Useful in organic cultivation: 1 = of use in organic crop growing, 2 = not useful,

Potato production

The International Organisation for Biological and Integrated Control of Noxious Animals and Plants (IOBC) has published crop specific Integrated Production-guidelines for field grown vegetable including potato (37).

Table 13. Best potato growing practice (excluding seed production) recommended by IOBC

Function	Preferred options	Strict rule or prohibition
Rotation	1 in 4 years. Winter cereals are suitable previous crops. Avoid alfalfa as previous crop (*Rhizoctonia* risk).	Potatoes must not to be grown more than 1 in 3 years to prevent nematode problems (avoidance of other Solanaceous crops). In nematode infested fields and in absence of cyst nematode resistant cultivars potatoes must not be grown in more than 1 in 7 years.
Cultivars	Cultivar diversity within the farm should be considered. Cultivars with a broad spectrum of resistance to major virus diseases and "field resistance" to late blight should be used. In nematode-infested fields, only cultivars with high tolerance to one or more of the nematode species or their dominating pathotypes should be grown.	
Cultivation	Ploughing is the recommended technique of soil cultivation, for "optimal" seedbed preparation, and weed control.	
Nutrient management	Plant analysis for nitrogen input (in addition to Nmin-analysis) is recommended.	Crop specific validated N advice systems are mandatory when available. Nitrogen supply pre-planting must not exceed 75% of the total supply in northern conditions, 50% in southern conditions, respectively. In sub-arctic regions, all nitrogen can be applied pre-planting.
Pests	Aphids: Straw mulch to reduce aphid infestation is recommended	Available selective aphicides must be used and applied according to national/ regional recommendations.
	Colorado potato beetle: Selective methods (e.g. *B. thuringiensis tenebrionis* or insect growth regulators should be preferred. Use of forecasting models where available	Insecticides against Colorado potato beetle (where established) must be used only according to threshold levels.
	Agriotes spp. (wireworms): should be monitored (e.g. sex pheromone or bait traps).	Soil insectides applied as placed (band) treatments.
	Cutworms: Irrigation in years with early droughts is recommended	
	Nematodes: In nematode-infested fields, only cultivars with high tolerance to one or more of the nematode species or their dominating pathotypes should be grown	No nematicides are allowed.
	Slug baits should only be used in exceptional cases.	
Diseases	For Late Blight the use of resistant/tolerant cultivars with low susceptibility is the most appropriate prevention. Highly susceptible cultivars should not be grown. Copper should not be used.	Fungicide treatments must be based on forecasting models if available. Copper input must be minimised. For *Rhizoctonia*, seed treatment is permitted only if threshold levels for tubers with sclerotia (black spore clusters) are exceeded.
Weeds		Priority must be given to mechanical weed control. Pre-emergence herbicides are not permitted. Post-emergence herbicides are only permitted unexceptional and clearly defined circumstances.
Destruction of foliage	Preference for mechanical canopy removal	
Habitat management	Promote ecological infrastructures enhancing pest natural enemies (e.g. grass strips, wildflower strips).	
Hygiene harvest		Potato dumps must be destroyed.

VI PESTICIDE REDUCTION INFORMATION

Reductions in pesticide residues can be achieved by encouraging good practice for potatoes crops. A good disease forecasting system can significantly decrease fungicide usage. For Late blight there are six different decision support systems (DSS) for the control of late blight tested in European validation trials: Simphyt, Plant-Plus, NegFry, ProPhy, Guntz-Divoux/Milsol and PhytoPre+2000. The results showed that the use of these decision tools reduced fungicide input by 8-62% compared to routine treatments (38).

Biological agents are also used to control or prevent fungal diseases. It has been shown that oils originating from garlic, peppermint, rosemary and thyme could reduce storage diseases in potato and in some cases increase yield by about 30% (39)

New methods for potato foliage control before harvest such as steam defoliation via a commercial steam weeder instead of usage of desiccants like sulphuric acid could be an option to reduce herbicide use (40).

VII INFORMATION ON QUALITY AND COSMETIC STANDARDS, MARKETING STRATEGIES

Standards

In the EU the Council Regulation on organic agriculture (EEC) No.2092/91 has been introduced to ensure the authenticity of organic farming methods and quality of organic products. It describes the practices and inputs which may be used in organic farming and growing, and regulates labelling, processing, marketing and inspection of organic products (41).

The Compendium, which is based on, and complies with, Council Regulation (EEC) No. 2092/91, as amended, sets out the standard for organic food production that must be complied with in the UK. (42)

Some member countries have published additional governmental standards. Furthermore there are additional private standards for organic farming published by certification bodies (e.g. Naturland, Bioland, Soil Association etc.) which represent an even higher level of farming standards in many countries.

Marketing

Prices of organic potato in conventional markets vary due to intense competition from conventionally grown potato, variable production costs, and government subsidies. Organic producers are addressing many obstacles when marketing organic potatoes.

In order to keep their 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 on their own niche markets, market stalls, farm shops, etc (43).

In many countries policies have been introduced to increase the share of and stimulate organic farming. Some of the measures include: area targets, conversion subsidies and 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 reduce Value Added Tax (VAT) for organic products to 0%, while maintaining VAT on non-organic food products. A lower VAT would normally lead to a reduction in consumer prices of organic food and to higher prices for farmers (44).

VIII CONCLUSIONS AND RECOMMDENATIONS

Organic potato production is very small in Europe and although it is steadily growing, it is not foreseen that a large number 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 increase the share of and stimulate organic farming such as 'Green Financing' in the Netherlands, new financial and fiscal instruments still need to be introduced.

We have seen that most seed and ware potato is produced using pesticides with serious health and environmental hazards. We need to change the bulk of the conventional production towards pesticide use reduction. Given the diversity of IPM and ICM guidelines in Europe (not only for potato), a set of minimum criteria should be laid out for potato and per crop.

But 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 while crop specific standards shall be adopted on a voluntary basis (45). This is a major set-back because in this process the necessary level of detail will be lost. Therefore, PAN Europe calls for crop specific standards established at the national level and applied on a compulsory basis, following a set of key elements. The introduction and implementation of crop-specific standards must be accompainied by adequate advise and training for farmers provided by independent advisory systems and financed by a levy on pesticides.

Key elements for general Integrated Crop and Pest Management standards should be, at a minimum:

1 – A soil structure serving as an adequate buffering system for agriculture;

2 – A crop rotation frequency enhancing a balanced population of soil organisms, preventing outbreak of soil-borne pests;

3 – Use of the best available pest-resistant (non-GMO) crop varieties;

4 – Optimal crop distance and crop management to prevent growth of fungi;

5 – Availability of refuges for natural enemies of pests and for the prevention of pesticide-resistant pests;

6 – Economical nutrient management on the basis of information of nutrients already present in the soil and of the soil structure, and dosage only on the crop;

7 – In principle only mechanical weeding (or other non-chemical methods like the use of heat); only exception in case of bad weather conditions;

8 – Use of pesticides based on information of presence of pests (scouting, traps, on-line forecasting services) and only the use of selective (not harming beneficial organisms) pesticides which are not persistent, bio-accumulative or toxic;

9 – Priority is given to the use of "green" (non-synthetic) pesticides and pest-preventive substances;

10 – Minimal material resources input (46).

These general standards would translate in a set of minimum standards for each crop. For ware potatoes, key elements for Integrated Crop and Pest Management standards are presented in Table 14.

Table 14. Key elements for an Integrated Crop and Pest Management system for ware potatoes

1. Soil estructure	- Minimum clay % and humus %
2. Crop rotation	- 1:4; higher frequency wanted in the future (1:6) - Analysis of nematodes on 25% of surface area per year
3. Varieties	- Priority to late blight resistance and early potato varieties - Nematode resistance
4. Fungi management	- A low number of plants per meter, - Working remnants of former crop under the soil
5. Refugia	- 2% of surface area wild herbs/flowers; could coincide with the non-spraying/nutrient zone - Maintaining and creating hedges and grassy banks
6. Nutrient management	- In winter, sow green catch crop - Nitrogen-loss must be < 200 kg/ha; in two years lowered to 150 kg/ha - If P2O5 concentration > 60, no use of P-fertiliser - If P2O5 concentration < 60, maximum P2O5-loss 35 kg/ha
7. Weeding	- Only mechanical weeding before and during the crop season; only exemption are weather conditions by written authorisation of the certifying organisation
8. Pesticide use	- Use of *Phytopthora* alert system - Maximum use of 10 kg/ha of active ingredient; in two years lowered to 8 kg/ha
9. Non-chemical pesticides	- Use of plant reinforcing substances, bentonite, citrex
10.Resource management	- No use of groundwater as water supply

Source (46)

As we have seen from the previous chapters, pesticide use reduction is technically achievable. Consumers are also aware of the hazards of pesticides and worried with the level of pesticides residues in food. There is the 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. Examples of this type of "food chain" approach are, for example, the self-certification scheme recently started by Legambiente (the largest Italian environmental organisation) for products without pesticides residues or 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 first example, the production of potatoes is based in Integrated Pest Management guidelines approved for use in the region, supplemented with further restrictions in terms of number and timing of spraying. Farmers are part of agriculture cooperatives with their own advisory system and in addition Legambiente outsourced the technical support to farmers to an independent consulting firm. Produce is priced slightly above the conventionally grown potatoes, a price that consumers are willing to pay for a product that guarantees no pesticides residues (47).

In the second example, 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 units of other highly hazardous pesticides defined on the basis of their acute and chronic toxicity, ecotoxicity, the impact on beneficial organisms and resistance management. Potatoes are priced between conventional and organically grown potatoes, to give farmers a fair return for high quality produce in a healthy environment (48).

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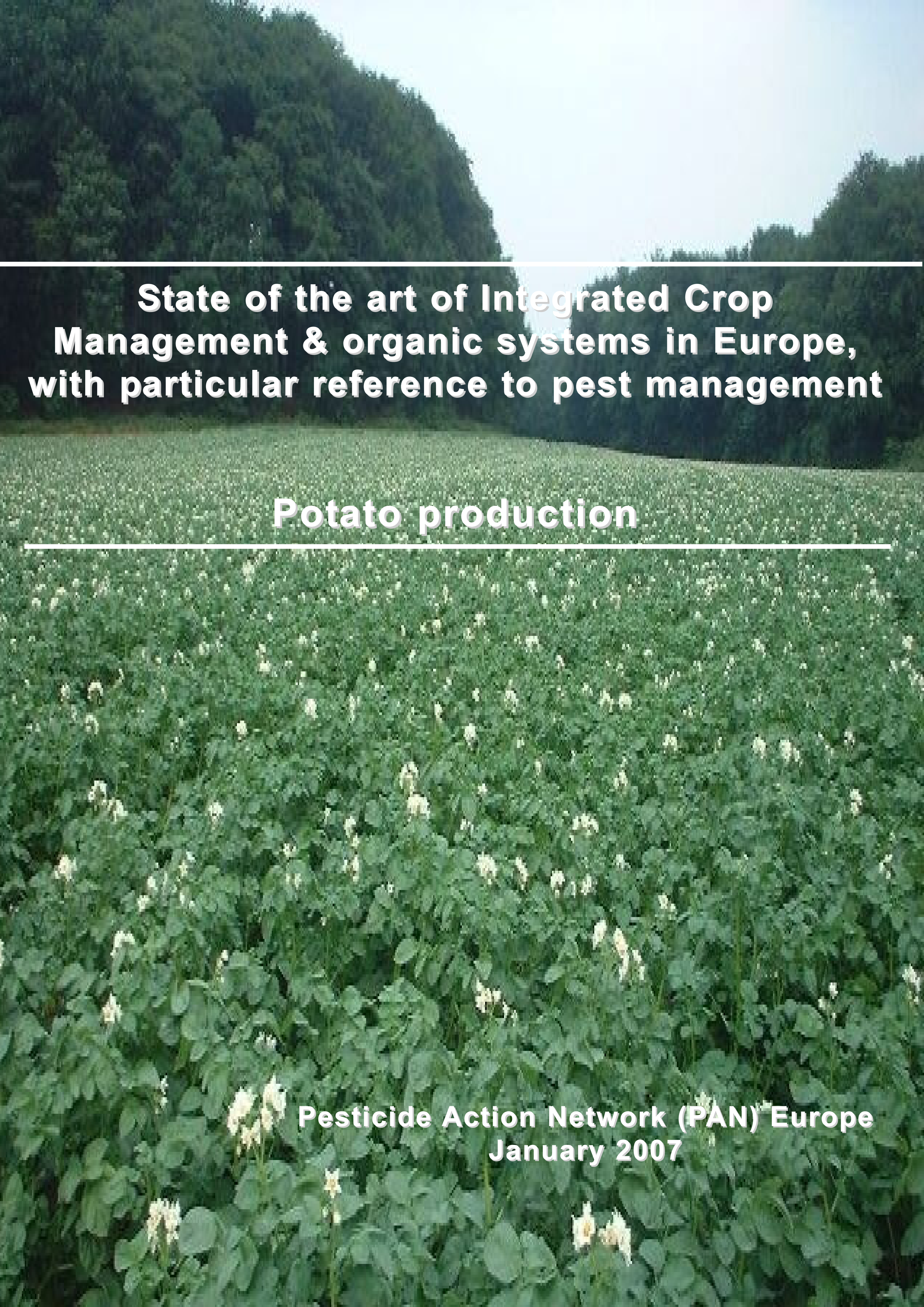

State of the art of Integrated Crop Management & organic systems in Europe, with particular reference to pest management

Potato production

Pesticide Action Network (PAN) Europe
January 2007

Potato production

Intensive conventional farming, which includes pesticide, chemical fertilisers and growth regulators application, use of heavy machinery and monoculture aims to maximize crop yield. Nonetheless, it is a dominant cause of biodiversity decline and environmental pollution. Pesticide usage and pesticide residues damage wildlife resulting in a declining number of natural enemies; heavy machinery damages soil structure and monoculture cropping leads to the deterioration of nutrition levels with a corollary of pests outbreaks. There is a growing concern among consumers about the health effects of growing (multiple) pesticide residues in food (1), hence the increasing demand for organically produced food and raising interest among producers to convert their production to organic.

Organic potato producers face some difficulties in terms of dealing with adequate plant nutrients, especially nitrogen application; weed, insect and disease control issues; profitability and marketing issues, among others. Regarding pest management, several non-chemical techniques are used for pest control, including: selection of resistant and tolerant varieties, crop rotation, destroying crop debris, biological control. Crop management includes careful timing of planting and harvest in order to avoid pests, controlled irrigation, understanding pest life cycles and all the circumstances that may influence the plant vitality to prevent damage and forecast threshold levels.

This review focuses on experiences of organic potato production in different European countries, common pests and diseases in potato production and chemical vs non-chemical pest control methods. This review and a briefing are available at: http://www.pan-europe.info/publications/index.htm).

I. SOME INDICATIONS OF CONVENTIONAL PRODUCTION AND PESTICIDE USE

According to Eurostat, production of potatoes in the 25 EU Member States in 2002 was 6.7 million tons, with an agricultural area of 2 million hectares. The 10 new Member States made up 47% of this area. The average yield was 28.65t/ha, with an average yield of 37.14 t/ha in EU-15 countries vs an average yield of 18.9 t/ha in the 10 new Member States. Yields higher than 40t/ha were recorded in some Western European countries: Belgium, Denmark, Germany, Spain (La Rioja), France, the Netherlands, Ireland, Switzerland and the United Kingdom (2), while most Eastern and Southern European countries have an extensive production engaging relatively large areas under potato production with rather low yield harvested. The following countries have an average potato yield 16.8 t/ha and are well below the 25 EU average: Albania, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Iceland, Latvia, Republic of Moldova, Lithuania, Former Yugoslav Republic of Macedonia, Portugal, Romania, Russian Federation, Serbia and Montenegro, Slovakia and Ukraine (3).

The largest areas under potato production as a proportion of utilised agricultural area are in regions of Belgium, the Netherlands and Poland, with more that 5% of the area under potato production. Areas in Portugal, Northern Spain, Bulgaria, Romania, Estonia, Latvia, Lithuania and England rank between 2.5 and 5% of the area under potato production (2).

Indicators of conventional use of pesticide in potatoes are difficult to find in the scientific literature. We opted to provide one complete and detailed case study on the national level (for the UK) that might illustrate the current situation in conventional potation production in Europe. The data originates from a survey about the overall use, extent and quantities of pesticide formulation and active ingredients used in arable crops in all regions of Great Britain carried out by the Department for Environment, Food and Rural Affairs and The Scottish Executive Environment and Rural Affairs Department (4).

Pesticide use in potatoes in Great Britain in 2004

All potato production in Great Britain - both ware (grown for human consumption) and seed - is grown with application of fungicides. 62.6% of ware and 90% of seed potato area were treated with insecticides. Herbicides are used in more than 95% of the fields under seed and ware potatoes. 72% area of ware crop and 97.9% of seed potato received seed treatments. Only 0.1% ware and seed potato area received no pesticide treatments.

Table 1 - Percentage of area under potatoes treated with pesticides in Great Britain

Chemical group	Ware potatoes	Seed potatoes
Insecticides	62.6	90.0
Fungicides	100.0	100.0
Herbicides & des-iccants	95.9	98.6
Sulphuric acid	21.2	85.7
Growth regulators	11.9	0.0
Molluscicides & repellents	29.1	25.1
Seed treatments	72.0	97.9
Not treated	0.1	0.0

During the vegetative phase ware potato receives 14.5 spray rounds of all pesticides and is treated with 19.4 different products. The biggest portion of those treatments accounts for fungicide spray. 10.7 spray rounds and 17.5 products are applied in seed potatoes, with highest percent of fungicides used.

Most commonly used fungicides

As for the five most commonly used fungicides, they are applied mostly for the control of late blight (Phytophthora infestans). Fluazinam is also effective against white mold (Sclerotinia sclerotiorum). Dimethomorph is also used to control rot.

Table 2 - Most commonly used fungicides in ware and seed potato in Great Britain

	Kg of a.i./ha	Proportion of area treated with a.i.	Average number of applications
Ware potatoes			
Cymoxanil/ maneb	1.415	0.27	4.12
Fluazinam	0.133	0.22	3.79
Cyazofamid	0.079	0.09	2.02
Mancozeb	1.392	0.06	3.62
Dimethomorph/ mancozeb	1.458	0.06	2.11
Seed potatoes			
Cymoxanil/ maneb	1.423	0.33	3.34
Fluazinam	0.144	0.15	3.00
Cymoxanil	0.072	.012	2.85
Cyazofamid	0.078	0.07	2.00
Dimethomorph/ mancozeb	1.479	0.05	1.50

Most commonly used herbicides

Among the five most commonly used herbicides in Great Britain, linuron is thought to be carcinogen, endocrine disruptor, developmental and reproductive toxin and ground water contaminant. Also according to PAN Pesticides Database (http://www.pesticideinfo.org), metribuzin is developmental and reproductive toxin, cholinesterase inhibitor and potential ground water contaminant and paraquat is acutely toxic.

Table 3 – Most commonly used herbicides in ware and seed potato in Great Britain

	Kg of a.i./ha	Proportion of area treated with a.i.	Average number of applications
Ware potatoes			
Linuron	1.17	0.24	1.00
Diquat/paraquat	0.46	0.22	1.03
Diquat	0.44	0.18	1.40
Glyphosate	1.09	0.08	1.02
Metribuzin	0.58	0.06	1.18
Seed potatoes			
Linuron	10.20	0.36	1.00
Paraquat	0.511	0.22	1.00
Diquat/paraquat	0.46	0.21	1.00
Diquat	0.40	0.11	1.76
Metribuzin	0.57	0.09	1.15

Most commonly used insecticides

Although widely used, aldicarb is a extremely toxic nerve poison. The acute toxicity of aldicarb is one of the highest of currently used pesticides. It is classified by the World Health Organisation as a extremely hazardous (Ia group). Oxamil is listed as a highly hazardous pesticide (Ib) and with pirimicarb acts as a cholinesterase inhibitor. Pymetrozine is believed to have carcinogenic effects.

Table 4 – Most commonly used insecticides in ware and seed potato production in Great Britain

	Kg of a.i./ha	Proportion of area treated with a.i.	Average number of applications
Ware potatoes			
Pirimicarb	8.24	0.44	1.34
Lambda-cychalotrin	266	0.23	1.62
Pymetrozine	2.18	.013	1.51
Oxamyl	51.41	0.07	1.00
Aldicarb	13.30	0.06	1.00
Seed potatoes			
Lambda-cychalotrin	0.006	0.34	2.58
Pirimicarb	0.11	0.23	2.33
Deltamethrin/pir-imicarb	0.09	0.12	1.83
Pymetrozine	0.12	0.12	1.32
Lambda-cychalotrin/ pirimicarb	0.12	0.12	2.67

Pesticides used in conventional potato production in the UK have serious health hazards: 7 most commonly used pesticides in Great Britain are classified as carcinogenic. WTO classifies oxamil as highly hazardous (Ib group) and aldicarb as extremely hazardous (Ia group). Seven pesticides have been linked to endocrine disrupting effects and/or to act as a developmental or reproductive toxin. Six chemicals are considered ground water contaminants.

Residues of pesticides in conventioanally grown food are also a serious threat to consumers. Conventionally grown potatoes are among the worst crops in terms of pesticides residues in the UK and other European countries (1) (6).

Table 5 – Hazards associated with the most commonly used pesticides in potato production according to several EU and International classifications

Active ingredient	WHO	Acute toxicity	Carcinogenic	Endocrine disruptor, developmental/reproductive toxin	Groundwater contaminant	Cholinesterase inhibitor
Fluazinam (fungicide)	Not listed	?	Possible	Not listed	Insufficient data	No
Maneb (fungicide	U	No	Yes	Suspected	Insufficient data	No
Cymoxanil (fungicide)	III	Slight	Not likely	Not listed	Insufficient data	No
Mancozeb (fungicide)	U	No	Yes			
Dimethomorph (fungicide)	U	Slight	Not likely	Not listed	Insufficient data	No
Imazalil (fungicide)	II	Moderate	Likely	Developmental and reproductive toxin	Insufficient data	No
Pencycuron (fungicide)	U	No	Not listed	Not listed	Insufficient data	No
Linuron (herbicide)	U	Slight	Possible	Suspected Endocrine disruptor, Developmental and reproductive toxin	Potential	No
Paraquat dichloride (herbicide)	II	Moderate	Not likely	Not listed	Potential	No
Diquat dibromide (herbicide)	Not listed	Moderate	Not likely	Not listed	Potential	No
Glyphosate (herbicide)	U	Slight	Not likely	Not listed	Insufficient data	No
Metribuzin (herbicide)	II	Moderate	Unclassifiable	Yes	Potential	No
Pirimicarb (insecticide)	II	Moderate	Not listed	Not listed	Insufficient data	Not listed
Lambda-cychalotrin (insecticide)	II	Moderate	Unclassifiable	Suspected endocrine disruptor	Insifficient data	No
Pymetrozine (insecticide)	Not listed	Slight	Likely	Not listed	Potential	Not listed
Oxamyl (Insecticide, Nematicide	Ib	Highly	Likely	Not listed	Insufficient data	Yes
Aldicarb (insecticide)	Ia	Extremely	Unclassifiable	Endocrine disruptor	Yes	Suspected
Deltamethrin (insecticide)	II	Moderate	Unclassifiable	Not listed	Insufficient data	No

WHO classification – The World Health Organization Recommended Classification of Pesticide by Hazard classifies all pesticide into four groups: Class Ia Extremely Hazardous, Class Ib Highly Hazardous, Class II Moderately Hazardous and Class III Slightly Hazardous (The classification is based primarily on the acute oral and dermal toxicity to the rat indicated by LD50 value, a statistical estimate of the number of mg of toxicant per kg of bodyweight required to kill 50% of a large population of rats). Source: (5)

II. SCALE OF ORGANIC PRODUCTION AND COMPARISON OF YIELD AND INCOME

There is a lack of comparable data of different countries because national statistics differ and the distinction between conventional and organic farming is not always clear.

The production and yield of organic in comparison with conventional potato production is not available except for a few countries. In Sweden, for example, the total production of table potatoes from areas with subsidies for organic farming is estimated at 12,600 tons. This is almost two per cent of the total production of ware potatoes. The potato yield per hectare is almost half (46 per cent) for the organic farming compared to the non-organic farming. The results are based on a mail survey with a sample of 209 out of about 950 holdings with table potatoes registered for organic farming subsidies (7).

When comparing the area used for organic potato in seven European countries, Germany is the country with the largest area under organic potato, however the portion in total organic production as well as in total potato production is considerably small. About 15% of all organic crops are under organic potato production in the Netherlands. Switzerland has the highest percent of organic potato in potato production.

Despite the lower yields and the small percentage of organic potato production in comparison with conventional, the gross margin for the farmer is far higher in organic production. Data from Germany and the UK, compiled in Table 7, indicates much higher gross margins, even if the payment for organic farming is excluded (8). The lower yields of organic potato are compensated for by higher prices and this is a key aspect of the profitability of the organic farming. Comparison between economic performance of conventional and organic potato in the UK, Germany and Poland indicates that in spite of lower yield harvested from the fields under organic potatoes, gross margins for organic production are two to three times higher that for conventional cropping in UK and Germany. In Poland the profit from organic farming greatly depends on the premiums. In Poland costs for organic potato are lower that for intensive and integrated conventional farm, in Germany costs of production are in generally higher that for conventional, whereas in the UK variable costs are somewhere in between the conventional early potato and potatoes for processing. The prices of early organic and organic potato for processing are approximately three time higher that the price of the conventional potatoes in both UK and Germany.

Costs are generally lower on organic tillage farms than on comparable conventional farms. Variable costs decline due to withdrawal of prohibited inputs but reseeding, fertility measures and higher labour inputs may reverse this tendency.

Table 6 – Area under organic potato production, percentage of organic potato in total organic and total potato production and the percentage increase of organic potato in selected European countries for the period 1998-2000

	Area under organic potato (ha)	% of organic potatoes in total organic production	% of organic potatoes in total potato production	% increase of area under organic potato production
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	0.74	189
United Kingdom	911	11.05	0.55	154

Source (8)

Table 7 – Comparison of yields and gross margin between conventional and organic potato production in Germany, UK and Poland

	Yield (t/ha)	Variable costs (€/t)	Gross margin (€/ha)
United Kingdom			
Conventional potatoes for food processing – East Anglia	42.5	3446	2138
Conventional early potatoes – South West England	22.5	2461	2525
Organic potatoes	25.0	3037	7225
Germany			
Conventional potatoes for processing - Brunswick	41.9	1580	2275
Conventional early potatoes – North-west coastal area	27.2	2001	2813
Organic potatoes for processing - Brunswick	25.1	1645	5052
Organic early potatoes - Brunswick	16.3	2556	5816
Poland			
Best conventional farms intensive	44.7	1703	1077
Best conventional farms integrated crop management	24.5	912	281
Best organic farms	21.0	821	180 (without organic premium) 788 (with organic premium)

Source: (9), (10)

III. HOW INSECT PESTS ARE MANAGED

Producers of organic potatoes use alternative approaches rather than artificial fertilizers and pesticides. These include: crop rotation, selecting resistant cultivars, good soil management, planting disease-free seed, non-chemical weed control, usage of blight warnings and decision support systems, correct storage, among other techniques. All these methods can and are normally used in Integrated Crop Management systems and are effective to reduce pesticide use. But while in organic production there are precise guidelines limiting the number of pesticide active substances that can be used and number of applications, in Integrated Crop and Pest Management systems the guidelines and the degree of implementation of those guidelines varies between countries and regions.

Overall plant-health considerations

• It is recommended that organic potatoes be grown in a minimum of a 4-year rotation to minimize yield losses from soil-borne diseases such as Rhizoctonia, Fusarium and Verticillium.

• General soil fertility is maintained by a well-planned management system involving rotations, legumes, straw and composted manure.

• Whole seed ought to be planted for the whole uncut seed tubers are less likely to become infected with soil borne diseases than cut seed pieces.

• Vigorously growing potato plants are more resistant to insects and diseases than plants under stress. Adequate soil moisture in the presence of adequate plant nutrition will assist in maintaining overall plant health.

• Potatoes should be planted after risk of frost has passed and when rapid emergence will reduce risks of seed decay.

Most important pests that cause significant damage to potato

Colorado potato beetle (CPB)

Colorado potato beetle (*Leptinotarsa decemlineata*) is one of the most widespread and destructive potato pests. It feeds on the foliage of potatoes and if left uncontrolled it can completely defoliate potato plants, resulting in reduced tuber size or plant death. CPB is difficult to control without insecticide usage. However, some non-chemical measures can be taken to reduce the population of Colorado potato beetle:

• Isolating the field from areas where potatoes were planted in previous seasons;

Colorado potato beetle (*Leptinotarsa decemlineata*)

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• Crop rotation (excluding tomato, camsicum and potato family plants) reduces and delays Colorado potato beetle population build-up (11);

• Flaming can control overwinter CPB if applied between potato emergence and 25cm in height when the plant is at the most tolerant phase(12).

• Using plastic-lined trenches as a barrier to CPBs entering a potato field (13).

• Canadian researchers have developed a portable field-edge trap to prevent overwintering pests from entering potato (14).

• Some researches has shown that mulching with wheat or rye straw may reduce CPB ability to locate potato fields, and the mulch creates a microenvironment that favours CPB predators. (15)

• In areas where CPB is a serious threat to potato crops the priority should be given to the early-maturing varieties that develop potato tubers before the pest population spreads throughout the field.

CPB has several natural enemies, predators and parasites. As examples of **predators** we have ladybirds, lacewings, predatory stink bugs and spiders. As examples of **parasites** we have *Doryphorophaga doryphorae* and *D. coberrans*, two species of fly that parasitize CPB larvae; a wasp, *Edovum puttleri*, parasitizes eggs, and two parasitic nematodes *Heterorhabditis* species and *Steinernema* species (16). However, only a few are produced for the commercial use, such as *Bacillus thuringiensis var tenebrionis* (Bt), a biological insecticides against potato beetle larvae and fungus *Beauveria bassiana*, effective against both adult and larvae stages. The effectiveness of these biological controls can be increased by providing pollen and nectar sources for beneficial insects along field borders or by planting insectary strips in the field.

Aphids

The most common aphids found in potato fields are: Green Peach Aphid (*Myzus persicae*); Potato Aphid (*Macrosiphum euphorbiae*); glasshouse and potato aphid (*Aulacorthium solani*); buckthorn/potato aphid (*Aphis nasturtii*); shallot aphid (*Myzus ascalonicus*); violet aphid (*Myzus ornatus*); black bead aphid (*Aphis fabae*); bulb and potato aphid (*Rhopalosiphonius latysiphon*). Aphids cause significant damage only in large numbers as a consequence of their feeding on sap. Attacked parts, especially young shoots, leaves and flowers become disordered, weak and eventually wilt. Yield losses are more severe due to virus diseases that are transmitted by some species. *Myzus persicae* is the main vector of potato leaf roll virus (PLRV) and potato virus Y (PVY). The standards of organic farming require the use of organically grown seeds in organic potato farming. Therefore, a high quality of seed potatoes (virus-free and healthy seed) is essential. Viral diseases are effectively controlled by the use of clean seed, careful removing diseased or abnormal plants, early top-killing (desiccation) and virus resistant cultivars. Controlling overwintering weeds on which aphids may be present and inspecting overwintered and imported plants in greenhouses since they are often the source of initial infestation of spring transplants is useful measure in preventing virus diseases. According to German studies, the early lifting of green crop tubers for seed production in the middle of July is an effective way to reduce virus diseases when there is a high pressure of aphids (17).
The spring migrations of the peach potato aphid and cabbage aphid into potato crops can be forecast using data from a network of special suction traps and information on winter temperatures. For example, information on aphid activity and forecasts in Great Britain can be obtained from the Rothamsted Insect Survey (18). Using these forcasts, farmers can target control measures only when needed.

Green Peach Aphid (*Myzus persicae*)

© Scott Bauer, USDA, www.insectimages.org.jpg

Wireworms and white grubs

(*Agriotes lineatus, A. obscurus, A. sputator*)
Wireworm larvae tunnel deeply into the tubers causing loss in quality and providing entrance for secondary pests and microorganisms, which can lead to rotting. These soil insects, primarily wireworms and white grubs, can severely damage seed pieces and tubers. Position in the rotation

Click beetle (*Agriotes lineatus*)

and length of any previous grassland are important. High wireworm populations are usually found in fields in long-term grassland and can cause severe damage in potato crops which follow grasslands. Methods to reduce wireworm populations cover:

- Pre-crop sampling to detect wireworm infestation by soil sampling or bait trapping method;
- Avoid wireworm infested fields for growing potatoes;
- Examine the mother tubers after planting of the early crop for signs of wireworm;
- Rotation with legumes including peas and beans (19);
- Earlier harvest, and as soon as tubers mature;
- Thorough soil cultivation before ridging in the autumn when wireworms are in upper layers of the soil profile (20).

Cutworms

Cutworms are caterpillars of nocturnal moths that feed on roots and stems and tunnel into tubers of potato plants, generally during dry weather. The most common in potatoes are: turnip moth (*Agrotis segetum*), large yellow underwing moth (*Noctua pronuba*), garden dart moth (*Euxoa nigricans*), silver y moth (*Autographa gamma*), rosy rustic moth (*Hydraecia micacea*), tomato moth (*Lacanobia oleracea*), angleshades moth (*Phlogophora meticulosa*), ghost swift moth (*Hepialus humuli*) and garden swift moth (*Hepialus lupulinus*). There are no measures that can prevent stem damage. If tuber damage is found the crop should be lifted promptly to limit further damage.

Large yellow underwing moth (*Noctua pronuba*)

Potato Flea Beetle

Flea beetles (*Epitrix spp., Psylloides affinis*) cause the small shot-hole damage to leaves when the plant is still small. These tiny beetles overwinter as adults and may appear in fields very early in the season and cause serious damage to young plants. Row covers could be used, but can be expensive. Crops under row covers usually produce earlier yields.

Damage in the leaves caused by potato flea beetles (*Epitrix spp.*)

Nematodes

Nematodes in potato crops are a very severe problem. To their significance as pests contributes the fact that the seed potatoes can not be sold within the UK unless grown in land free of potato cyst nematodes. The most common and troubles some nematode species in Europe are:

- Potato cyst nematodes *Globodera pillida* and *G. rostochiensis; Meloidogyne spp.*
- Needle Nematode (*Longidorus sp.*),
- Stubby Root Nematode (*Trichodorus sp.*),
- Potato Tuber Nematode (*Dytilenchus destructor*) and Stem Nematode (*Dytilenchus dipsaci*), and
- Root Lesion Nematode (*Pratylenchus penetrans*)

The population of nematodes can be reduced by growing tolerant cultivars, as well as by using other non-chemical methods:

- Green manure crops can reduce nematode populations. Sudan grass, white mustard, rapeseed and rye have an allelopathic effect on nematodes by releasing toxic compounds into soil. These compounds inhibit weeds as well (21);
- Land intended for potatoes ought to be tested for the presence of potato cyst nematode and if the land proves to be infested, organic potato should not be grown;
- Some crop rotation rules should be followed. Potatoes should not be grown on the same land in less than five years and the crops included into the rotation should be resistant to potato cyst nematodes species;
- If only a small amount of potato cyst nematodes is present, opt for the appropriate resistant varieties (22).

IV HOW DISEASES ARE MANAGED

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

• Using disease-free tubers, seeds
• Destroying crop residues
• Eliminating cull piles
• Eliminating volunteers
• Considering prevailing wind directions
• Removing potato plant foliage (dehaulming) in advance of harvest (2 weeks). The destruction of haulm before the tubers are harvested reduces the risk of spreading the viruses by aphids in seed potatoes, as well as minimizing tuber infection by blight
• Maintaining good rotation with non-host species (tomatoes, peppers, aubergines are all hosts for the same diseases)
• Growing resistant cultivars
• Using low-generation certified seed reduces the risk of seed-borne diseases
• Using whole seed reduces risk of spreading disease during cutting
• Isolation may reduce the risks from diseases such as late blight
• Choosing cooler sites to reduce the rate of spore formation
• Choosing early maturing (early bulking) varieties
• Adjusting crop density to reduce humidity in a microclimate
• Using local forecasting techniques and models (e.g. Blight-Mop)
• Using efficient spraying equipment
• Proper storage
• Drip irrigation system, the right type of water management based on water prevent occurrence of blight
• Using the Smith period to identify periods of high risk of late blight spread, (when the temperature and humidity favour blight: two consecutive 24-hour periods in which the minimum temperature is 10 C or above and in each of which there are at least 11 hours with a relative humidity above 90 percent)

Late blight

Late blight (*Phytophthora infestans*) is one of the most damaging diseases with ability to spread quickly in favourable conditions. It is the major cause of the immense variation in yield between years. Fungicides based on copper have been the most effective and the organic potato production greatly relied on copper application. Nevertheless, copper is being ohased-out in organic farming in the European Union. From the 1st of January 2006 EU imposed regulations on the organic farmers to use no more than 6 kg of copper *per* hectare *per* year. Further reductions can be expected (23). Withdrawal of copper pesticides as a blight control and lack of alternatives remains the growers' main concern. Thus, the priorities should be set on finding strategies to minimize damage from late blight without the use of copper. (24)

Among the many initiatives to exchange best practices for the control of late blight is the Global Initiative on Late Blight (GILB), a network of researchers, technology developers and agricultural knowledge agents gathered with an aim to exchange ideas and opinions, and facilitates communication and access to information in order to improve management of potato late blight in developing countries (25). In Europe, EUCABLIGHT Potato Late Blight Network For Europe, is a European Commission project network funded under the 5th Framework Programme (26).

Other relevant blight networks for Europe are:

- EU-NET-ICP (European network for development of an integrated control strategy of potato late blight),
- Blightmop is a project that aims at developing a systems approach to control potato late blight that maintains yield and quality of organic potato. It involves integrated use of resistant varieties, existing agronomic strategies, alternative treatments that can replace synthetic and copper based fungicides, use of existing blight forecasting systems to optimise control treatments
- Ecopapa (the Enrichment of Potato Breeding Programs in Latin America and Europe with Resistance to Late Blight),
- Incopapa-project on "Exploitation of the genetic biodiversity of wild relatives for breeding potatoes with sustainable resistance to late blight", Funded by the European Union Program for International Cooperation (INCO).
- CEENP (The Central & Eastern European Network for Potato Research),
- EAPR.(The European Association for Potato Research)
- IHAR (The Mlochow Research Center of Poland's Plant Breeding and Acclimatization Institute)

Tackling the blight problem can be done by:

- planting early varieties-potatoes planted earlier tolerate blight infection better than those planted late
- planting healthy, blight-free seed
- selecting varieties with high blight resistance
- monitoring blight development on a daily basis
- heeding blight warnings
- removing haulms from infected plants
- harvesting the crop, once skins have set
- removing all blighted tubers during packing
- crop rotation with at least three to four years between potato growing, preferably with cereals or legumes.

Early blight

Early blight (*Alternaria solani*) can be kept under control in organic farming using a combination of strategies:

1. Plant potatoes in the dry season when the incidence of early blight is lower.
2. Avoid multiple plantings in the same area; old crops are sources of inoculum of early blight for the new

plantings. Select plots surrounded by grasslands and other non-hosts of this disease.

3. Avoid the use of overhead irrigation.
4. Use disease-free certified seed.
5. Seed-beds should be distant from old plantings. Inspect seedlings for any sign of disease and discard and destroy any that are suspected of being infected.
6. Increase the organic matter in the soil as much as possible, by using old manure and maize stalk. This will increase fertility and decrease nematodes. The use of nitrogen fixing legumes in the crop rotation scheme can also increase the fertility of the land and eliminate some of the inoculum.
7. Remove unharvested plant parts and crop debris.
8. Late maturing varieties have proved to be more resistant towards early blight (27).
9. The tuber skins should be well set at harvest and the potatoes, avoid harvesting under wet conditions.

Black scurf and stem canker

Thanatephorus cucumeris (syn. *Rhizoctonia solani*) is a seed borne disease that often causes yield losses and quality deficiency in organic potatoes. Black scurf has become a significant problem since the EU imposed the regulations that growers use only organically grown seed potato for organic potato production. Potatoes are more susceptible to *R. solani* before emergence. Planting seed tubers in warm soil and shallow seedbeds with pre-germinated seeds gives the plants a quick start and speeds the emergence of the shoots. Using certified seed free of the blak spore clusters, an adequate rotation and good volunteer control can prevent soil borne *Rhizoctonia* build up. Potatoes should be harvested as soon as the skin is set, before spore clusters are formed (28).

Common scab

Common scab is a disease whose importance is often overlooked as it causes no symptoms above ground and no or little effect on total yield. However, the main effect of the disease is lowered tuber quality. As a result of high level of common scab infection the portion of potatoes harvested that is saleable is considerable reduced. Minimising common scab involves keeping soil well drained, planting resistant varieties, and avoiding planting infected seeds. Green manure crops, such as rye, millet, and oat, have been reported to reduce the incidence of scab.

Storage diseases

Diseases which cause main losses during storage are pink rot (*Phytopthora erythoseptica*), black leg and soft rot (*Erwinia carotovora* ssp. *atroseptica*, *E. carotovora* ssp. *carotovora*), pythium leak, *Fusariums* dry rot and wilt, silver scurf (*Helmintosporium solani*), black heart, etc. Potatoes are stored successfully when the storage environment conditions (mainly temperature, humidity, oxygen and carbon dioxide concentration) are controlled and adjusted to requirements to potatoes. The disease occurrence on potato tubers whilst stored can be minimised by sorting the potatoes rigorously to exclude all infected or damages tubers, avoiding tuber damage during harvesting, storing and other operations and avoiding very susceptible varieties.

Viruses

The most economically important viruses in Europe are potato roll leaf virus, potato virus Y, potato virus X. The measures that can be applied to control viruses:

* Controlling the presence of virus in the seeds,
* Frequently cleaning hand tools while working,
* Removing infected potato plants from the field,
* Weeding in the field border,
* Controlling the population of vectors (aphids) and hosts for potato viruses (nightshades and volunteer potatoes),
* Seed-potato fields should be surrounded with crop borders that are not susceptible to the virus.

Varieties

Growing the varieties with resistance to the most important diseases and pests is one of the key factors in successful organic potato production. Many organisations and institutions through out the world are working on developing varieties that can be grown organically without pesticide inputs. Research on late blight resistant varieties suitable for organic cropping are the most intensive and of great importance as blight is a major limiting factor. The blight resistance breeding program is a continuous process because the blight fungus constantly develops the mechanisms to overcome the resistance and even the more horizontal resistance will eventually break down (29).

One of the most important groups of varieties that proved to have good resistance to late blight is called Sarpo and originates from Hungary. Research shows that this group 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 very slow blighters (30).
From National Institute for Agricultural Botany (NIAB) trials in 1998/99 the following varieties were recommended for organic potato growers: Cara, Cosmos, Valor and Jutlandia (31).

Swedish potato cultivars that are commercial varieties resistant to viruses and classified by the Nordic gene bank are:

ROSVA (NGB 3199), STINA (NGB 3228) and VETO (NGB 3256) are resistant to PVY. SEMLO (NGB 3200) are both resistant to PVY and PLRV (32).

Table 8. Potato varieties according to their resistance to different diseases

Resistance to	Resistant varieties
Early blight Alternaria solani)	Ackersegen, Agin 2792,Capella, Ewerest, Fink, Goya, Huron, Kolpashevsky, Maritta, Merrimack, Ontario, Rosa(1980), Russette, Sebago, Somerset, Varmas, Victor
Fusarium wild (Fusarium oxysporum)	Atlantic
Stem canker (Rhizoctonia solani)	Ackersegen, Amsel, Start (1966), SVP 82 1932 68, TA 11 605, TA 7 387, Torva, TP 8447
Dry rot (Fusarium spp)	Asva, Desiree, Great Scot, Oleva, Tiva, Torva
Ring rot (Clavibacter michiganensis ssp. sepedonicus)	Prof Wohltmann
Late blight on tubers (natural inoculum in field) (Phytophthora infestans)	Argyll Favourite, Aura, Black King, Bobbie Burns, Bonnie Dundee, Cara, Cardinal, Craigneil, Desiree, Early Market, Eclipse, Edinburgh Castle, Glenesk, Hunters Gold, Immune Ashleaf, Mighty Atom, Pentland Javelin, Remarka, Stirling Castle, Wilja
Late blight on foliage (natural inoculum in field) (Phytophthora infestans)	Argyll Favourite, Aura, Bonnie Dundee, Bute Blues, Cara, Crimson Beauty, Early Market, Early Rose, Eclipse, Edgecote Purple, Edinburgh Castle, Hunters Gold, Irish Cobbler, ,Kepplestone Kidney , Lumpers, Meins Early Round, Mighty Atom, Mr Bresee, Pentland Javelin, Puritan, Remarka, The Baron, Wilja, Yam

Source: (33)

Table 9. Potato varieties resistant to potato cyst nematode species

Resistance to	Resistant varieties
Globodera rostochiensis race 1,2, 3, 4 and 5	AM 76 1227, Amera, Artana, Atrela, Benol, Darwina, Dorett, Franzi, Jaerla, Karida, Loman 61 62N, Miranda, MPI 71 240 97, Optima, Padea, Palladia, Pino, Ponto
Globodera pallida race 1 and 2	Atrela, Benol, Morag, Vantage
Globodera pallida race 3	AM 78 3778, AM 78 3813, AM 80 3777, AM 81 940, AM 82 137, AM 83 1324, AM 83 307, DH 84 13 705, VE 7653, VE 843, VE 846, VE 849

Source: (19)

Table 10. Potato varieties resistant to potato cyst nematode species in the United Kingdom National List, 2002

Resistant to *Globodera rostochiensis*, pathotype Ro1: Accent, Navan, Admiral, Pentland Javelin, Amour, Pomeroy, Argos, Rathlin, Bimonda, Red Cara, Buchan, Revelino, Cabaret, Riviera, Cara, Rocket, Celine, Roscor, Dundrod, Saxon, Harborough Harvest, Sebastian, Horizon, Spey, Jamila (Atlas), Stemster, Kingston, Sunbeam, Kirrie, Tay, Maxine, Valor, Maris Piper, White Lady, Midas, Winston, Nadine
There are no cultivars on the National List with full resistance to *Globodera pallida*, pathotypes Pa1, Pa2, Pa3

Source: (20)

V HOW WEEDS ARE MANAGED

Potato competes very well with most weeds and can be grown without herbicides providing the good soil maintenance. If soil is moist enough, most weeds can be removed mechanically by cultivation, before the potatoes emerge. Weeds exert the most impact on potato growth during the first 2-4 weeks after crop emergence and it is crucial to be controlled at that time in order to prevent yield loss (34). Once the potato tops have met between the rows, forming a complete foliage layer, no further weed control will be possible. If it was well carried out before this stage any further weeds will be suppressed by the potato tops.

Weed control

• Post-plant cultivation (hilling, harrowing and hilling) is effective in controlling annual weeds, however, excessive cultivation or cultivation at the wrong time may reduce yield as a result of damaging roots, stolons or tubers
• Remove weeds while they are still at the seedling stage
• Choosing (where possible) fields with no major weed problems
• Flame weeding of weed seedlings before the potato tops emerge - this is expensive
• Mechanical weed control just before tops meet between rows
• Limited hand weeding of any large invasive weeds such as fat hen (*Chenopodium album*), cleavers (*Galium* spp.), redshank (P*olygonum persicaria*), knotgrass (*Polygonim aviculare*) or large docks (*Rumex* spp.)

It is very important to manage green nightshade weed (*Solanum physalifolium*) as it has been found to be very susceptible to late blight and can be carrying and transmitting potato virus. It is a great risk of disease inoculum to potatoes. The problem with mechanical weed management of this weed is that it has been observed to develop roots in the internodes when the stem gets in contact with the soil and it might limit the efficiency of harrowing and ridging. A crop rotation including cereals or perennial grasses will be the best way to manage green nightshade (35).

VI EXAMPLES OF BEST PRACTICES IN INTEGRATED PEST MANAGEMENT POTATO PRODUCTION

The tables below present the guidelines for best practices in potato production developed and applied by a consortium between Wageningen University, Laurus supermarket and a group of progressive farmers in the Netherlands (36).

Table 11. Hierarchy of IPM measures and coding of subtypes in potato production in Netherlands

Type of measure	Subtype
1. Prevention	1a. Healthy starting materials (plants, seeds) 1b. Hygienic measures on the farm/ field 1c. Condition/Treatment of the soil 1d. Cultivation and crop rotation 1e. Choice of crop and variety 1f. Time of planting/sowing 1g. Knowledge of diseases, pests and weeds
2. Technical measures for cultivation	2a. Scouting/crop quality damage threshold 2b. Plant distance and density 2c. Fertilizing 2d.Climate regulation in glasshouses 2e. Crop care
3. Systems for early warning and advice	3a. Use of weather systems and pests traps 3b. Decision supporting systems
4. Non-chemical crop protection	4a. Use of natural enemies of pests 4b. Mechanical/thermal foliage killing 4c. Mechanical techniques of weed killing 4d. Plant strengtheners 4e. Crop protection substances of natural origin 4f. Flooding 4g. Biological soil treatment
5. Chemical crop protection and application techniques	5a. Choice of substance 5b. Seed coating 5c. Spot application 5d. Low dosage system
6. Emission reduction	6a. Choice of substance (pesticides) 6b. Catch crop/ bigger cultivation-free zone

Table 12. Best practices recommendations for potato growers in Netherlands

IPM-measures to be implemented in potatoes growing	Coding measure subtype	Implementation grade in practice	Constraints	Contribution to lowering environmental pressure	Useful in organic cultivation	Short comments on measure
1. Chose the best resistant variety against Late Blight/*Phytopthora*	1e	1-2-3	2-3	2	1	First and for all it is important to chose the best *Phytopthora*-resistant variety. Dosing and frequency of treatment with fungicides can be reduced. Resistance against soil nematodes is also useful
2. Use of recent nematode-analysis of the soil for the choice of crop, rotation frequency and variety	1g	2-3	4	2	1	Nematodes giving root knot should be virtually absent. A wide crop rotation is the best strategy for avoiding accumulation of these nematodes. Some green plants are also capable of reducing the nematode-numbers.
3. Use of pesticides against *Rhizoctonia* on the basis of damage threshold	2a	2-3	3-4	4	2	Knowledge and use of *Rhizoctonia*-index is necessary. (Rhizoctonia is a soil-bound fungus and can give rise to stem and stolon canker)
4. Moderate fertilization with the use of stepwise dosage system	2c	2-3	2-3-4	3	1	Stepwise dosage system based on cropscan, analysis of foliage and/or analysis of minerals (N, P, K)
5. Chose the 'environmental' strategy in the decision supporting system (*) for *Phytopthora* management	3b	2-3	1-2-3-4-5	3	2	Instead of choosing 'low costs' or 'avoiding risks' the decision supporting equipment should be programmed on 'environment'
6. Use of GEWIS (**)	3b	2-3	1-2-4	3	2	GEWIS is a decision supporting system reducing the use of pesticides by advising the optimal spraying moment
7. Develop and use FAB-plan	4a	4	4	3	1	Use of Functional Agro Biodiversity (like small zones with wild herbs and flowers) raises the number of natural enemies of pests
8. Use mechanical foliage killing	4b	2-3	2-3	1	1	Burning or crushing foliage substitutes chemical treatment
9. Use mechanical weed killing	4c	2-3	2-3-4	1	1	Before planting mechanical weeding should be standard; after planting special equipment can kill weed mechanically in rows and even between plants ('finger weeders').
10. Choice of pesticides used	5a	2-3	4	2	2	Knowledge of unwanted effects of pesticides is missing
11. Avoid pesticides which kill natural enemies of pests	5a	3	4	3	2	Knowledge and awareness is missing in the agricultural world
12. treatment of seeds against aphids	5b	2	1	3	2	Use of a pesticide while sowing prevents full field spraying

Explanation of the codes used

<u>Coding measure subtype:</u> See Table 11

Implementation grade in practice: 1= used generally, 2 = use on front-running farms, 3 = use on experimental farms, 4 = strategy in development

Constraints: 1 = costs, 2 = labor, 3 = risks, 4 = risk perception, 5 = no authorization

Contribution to lowering environmental pressure: 1 = creating independence of chemicals, 2 = big, 3 = medium, 4 = small, 5 = no contribution

Useful in organic cultivation: 1 = of use in organic crop growing, 2 = not useful,

Potato production

The International Organisation for Biological and Integrated Control of Noxious Animals and Plants (IOBC) has published crop specific Integrated Production-guidelines for field grown vegetable including potato (37).

Table 13. Best potato growing practice (excluding seed production) recommended by IOBC

Function	Preferred options	Strict rule or prohibition
Rotation	1 in 4 years. Winter cereals are suitable previous crops. Avoid alfalfa as previous crop (*Rhizoctonia* risk).	Potatoes must not to be grown more than 1 in 3 years to prevent nematode problems (avoidance of other Solanaceous crops). In nematode infested fields and in absence of cyst nematode resistant cultivars potatoes must not be grown in more than 1 in 7 years.
Cultivars	Cultivar diversity within the farm should be considered. Cultivars with a broad spectrum of resistance to major virus diseases and "field resistance" to late blight should be used. In nematode-infested fields, only cultivars with high tolerance to one or more of the nematode species or their dominating pathotypes should be grown.	
Cultivation	Ploughing is the recommended technique of soil cultivation, for "optimal" seedbed preparation, and weed control.	
Nutrient management	Plant analysis for nitrogen input (in addition to Nmin-analysis) is recommended.	Crop specific validated N advice systems are mandatory when available. Nitrogen supply pre-planting must not exceed 75% of the total supply in northern conditions, 50% in southern conditions, respectively. In sub-arctic regions, all nitrogen can be applied pre-planting.
Pests	Aphids: Straw mulch to reduce aphid infestation is recommended	Available selective aphicides must be used and applied according to national/ regional recommendations.
	Colorado potato beetle: Selective methods (e.g. *B. thuringiensis tenebrionis* or insect growth regulators should be preferred. Use of forecasting models where available	Insecticides against Colorado potato beetle (where established) must be used only according to threshold levels.
	Agriotes spp. (wireworms): should be monitored (e.g. sex pheromone or bait traps).	Soil insectides applied as placed (band) treatments.
	Cutworms: Irrigation in years with early droughts is recommended	
	Nematodes: In nematode-infested fields, only cultivars with high tolerance to one or more of the nematode species or their dominating pathotypes should be grown	No nematicides are allowed.
	Slug baits should only be used in exceptional cases.	
Diseases	For Late Blight the use of resistant/tolerant cultivars with low susceptibility is the most appropriate prevention. Highly susceptible cultivars should not be grown. Copper should not be used.	Fungicide treatments must be based on forecasting models if available. Copper input must be minimised. For *Rhizoctonia*, seed treatment is permitted only if threshold levels for tubers with sclerotia (black spore clusters) are exceeded.
Weeds		Priority must be given to mechanical weed control. Pre-emergence herbicides are not permitted. Post-emergence herbicides are only permitted unexceptional and clearly defined circumstances.
Destruction of foliage	Preference for mechanical canopy removal	
Habitat management	Promote ecological infrastructures enhancing pest natural enemies (e.g. grass strips, wildflower strips).	
Hygiene harvest		Potato dumps must be destroyed.

VI PESTICIDE REDUCTION INFORMATION

Reductions in pesticide residues can be achieved by encouraging good practice for potatoes crops. A good disease forecasting system can significantly decrease fungicide usage. For Late blight there are six different decision support systems (DSS) for the control of late blight tested in European validation trials: Simphyt, Plant-Plus, NegFry, ProPhy, Guntz-Divoux/Milsol and PhytoPre+2000. The results showed that the use of these decision tools reduced fungicide input by 8-62% compared to routine treatments (38).

Biological agents are also used to control or prevent fungal diseases. It has been shown that oils originating from garlic, peppermint, rosemary and thyme could reduce storage diseases in potato and in some cases increase yield by about 30% (39)

New methods for potato foliage control before harvest such as steam defoliation via a commercial steam weeder instead of usage of desiccants like sulphuric acid could be an option to reduce herbicide use (40).

VII INFORMATION ON QUALITY AND COSMETIC STANDARDS, MARKETING STRATEGIES

Standards

In the EU the Council Regulation on organic agriculture (EEC) No.2092/91 has been introduced to ensure the authenticity of organic farming methods and quality of organic products. It describes the practices and inputs which may be used in organic farming and growing, and regulates labelling, processing, marketing and inspection of organic products (41).

The Compendium, which is based on, and complies with, Council Regulation (EEC) No. 2092/91, as amended, sets out the standard for organic food production that must be complied with in the UK. (42)

Some member countries have published additional governmental standards. Furthermore there are additional private standards for organic farming published by certification bodies (e.g. Naturland, Bioland, Soil Association etc.) which represent an even higher level of farming standards in many countries.

Marketing

Prices of organic potato in conventional markets vary due to intense competition from conventionally grown potato, variable production costs, and government subsidies. Organic producers are addressing many obstacles when marketing organic potatoes.

In order to keep their 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 on their own niche markets, market stalls, farm shops, etc (43).

In many countries policies have been introduced to increase the share of and stimulate organic farming. Some of the measures include: area targets, conversion subsidies and 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 reduce Value Added Tax (VAT) for organic products to 0%, while maintaining VAT on non-organic food products. A lower VAT would normally lead to a reduction in consumer prices of organic food and to higher prices for farmers (44).

VIII CONCLUSIONS AND RECOMMDENATIONS

Organic potato production is very small in Europe and although it is steadily growing, it is not foreseen that a large number 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 increase the share of and stimulate organic farming such as 'Green Financing' in the Netherlands, new financial and fiscal instruments still need to be introduced.

We have seen that most seed and ware potato is produced using pesticides with serious health and environmental hazards. We need to change the bulk of the conventional production towards pesticide use reduction. Given the diversity of IPM guidelines in Europe (not only for potato), a set of minimum criteria should be laid out for potato and for every crop.

But 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 while crop specific standards shall be adopted on a voluntary basis (45). This is a major set-back because in this process the necessary level of detail will be lost. Therefore, PAN Europe calls for crop specific standards established at the national level and applied on a compulsory basis, following a set of key elements. The introduction and implementation of crop-specific standards must be accompainied by adequate advise and training for farmers provided by independent advisory systems and financed by a levy on pesticides.

Key elements for general Integrated Pest Management standards should be, at a minimum:

1 – A soil structure serving as an adequate buffering system for agriculture;

2 – A crop rotation frequency enhancing a balanced population of soil organisms, preventing outbreak of soil-borne pests;

3 – Use of the best available pest-resistant (non-GMO) crop varieties;

4 – Optimal crop distance and crop management to prevent growth of fungi;

5 – Availability of refuges for natural enemies of pests and for the prevention of pesticide-resistant pests;

6 – Economical nutrient management on the basis of information of nutrients already present in the soil and of the soil structure, and dosage only on the crop;

7 – In principle only mechanical weeding (or other non-chemical methods like the use of heat); only exception in case of bad weather conditions;

8 – Use of pesticides based on information of presence of pests (scouting, traps, on-line forecasting services) and only the use of selective (not harming beneficial organisms) pesticides which are not persistent, bio-accumulative or toxic;

9 – Priority is given to the use of "green" (non-synthetic) pesticides and pest-preventive substances;

10 – Minimal material resources input (46).

These general standards would translate in a set of minimum standards for each crop. For ware potatoes, key elements for Integrated Pest Management standards are presented in Table 14.

Table 14. Key elements for an Integrated Pest Management system for ware potatoes

1. Soil estructure	- Minimum clay % and humus %
2. Crop rotation	- 1:4; higher frequency wanted in the future (1:6) - Analysis of nematodes on 25% of surface area per year
3. Varieties	- Priority to late blight resistance and early potato varieties - Nematode resistance
4. Fungi management	- A low number of plants per meter, - Working remnants of former crop under the soil
5. Refugia	- 2% of surface area wild herbs/flowers; could coincide with the non-spraying/nutrient zone - Maintaining and creating hedges and grassy banks
6. Nutrient management	- In winter, sow green catch crop - Nitrogen-loss must be < 200 kg/ha; in two years lowered to 150 kg/ha - If P2O5 concentration > 60, no use of P-fertiliser - If P2O5 concentration < 60, maximum P2O5-loss 35 kg/ha
7. Weeding	- Only mechanical weeding before and during the crop season; only exemption are weather conditions by written authorisation of the certifying organisation
8. Pesticide use	- Use of *Phytopthora* alert system - Maximum use of 10 kg/ha of active ingredient; in two years lowered to 8 kg/ha
9. Non-chemical pesticides	- Use of plant reinforcing substances, bentonite, citrex
10.Resource management	- No use of groundwater as water supply

Source (46)

As we have seen from the previous chapters, pesticide use reduction is technically achievable. Consumers are also aware of the hazards of pesticides and worried with the level of pesticides residues in food. There is the 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. Examples of this type of "food chain" approach are, for example, the self-certification scheme recently started by Legambiente (the largest Italian environmental organisation) for products without pesticides residues or 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 first example, the production of potatoes is based in Integrated Pest Management guidelines approved for use in the region, supplemented with further restrictions in terms of number and timing of spraying. Farmers are part of agriculture cooperatives with their own advisory system and in addition Legambiente outsourced the technical support to farmers to an independent consulting firm. Produce is priced slightly above the conventionally grown potatoes, a price that consumers are willing to pay for a product that guarantees no pesticides residues (47).

In the second example, 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 units of other highly hazardous pesticides defined on the basis of their acute and chronic toxicity, ecotoxicity, the impact on beneficial organisms and resistance management. Potatoes are priced between conventional and organically grown potatoes, to give farmers a fair return for high quality produce in a healthy environment (48).

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