ANNEX 13

ARTHROPOD FAUNA OF CENTRAL AND NORTHERN EUROPEAN POTATO FIELDS WITH EMPHASIS ON BENEFICIAL SPECIES

Regulatory Support | Infobroking | Faunistics & Consulting

Literature survey

Arthropod fauna of Central and Northern European potato fields with emphasis on beneficial species

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2 Summary

A survey of the literature detailing the occurrence of arthropods in Northern European potato fields was conducted with the focus on beneficial arthropods feeding partially or entirely on potato pests.

Over the course of the current survey, 33 relevant publications concerning arthropods in the potato fields of Central and Northern Europe were identified. The numbers of studies conducted on individual groups of arthropods was found to vary greatly. A total of 74 families/superfamilies belonging to 14 different orders/superorders and the 3 classes Insecta, Arachnida and Diplopoda are reported in the literature as being found in northern European potato fields. Of these different taxonomic groups, 41 families/superfamilies included beneficial arthropods such as polyphagous and aphidophagous predators or parasitoids.

Arthropods dwelling on potato foliage can be divided into pests and beneficials. Pests include aphids (e.g. *Myzus persicae, Macrosiphum euphorbiae*), the Colorado potato beetle (*Leptinotarsa decemlineata*), some true bugs (e.g. *Adelphocoris lineolatus, Lygus rugulipennis*), leafhoppers (e.g. *Empoasca solani, Eupteryx atropunctata*) and butterflies (e.g. *Pieris napi, Pieris rapae*). Important beneficials are ladybird beetles (e.g. *Coccinella septempunctata, Propylea quatuordecimpunctata*), hoverflies (e.g. *Episyrphus balteatus, Syrphus vitripiennis*), lacewings (e.g. *Chrysoperla kolthoffi, Chrysopa phyllochroma*), parasitic wasps (e.g. *Aphidius ervi, Aphidius picipes*), predatory flies (e.g. *Platypalpus minutus*, *Dolichopus longicornis*) and some true bugs (e.g. *Anthocoris nemorum, Orius minutus*). Besides true bugs and predatory flies, the majority of foliage dwelling taxa was usually represented by less than 10 species.

Ground-dwelling arthropods in potato fields include ground beetles (e.g. *Pterostichus melanarius, Harpalus rufipes*), rove beetles (e.g. *Aloconota gregaria, Atheta fungi*), clown beetles (*Hister bisexstriatus, Margarinotus spec*.) spiders of the families Linyphiidae (e.g. *Erigone atra, Bathyphantes gracilis*) and Lycosidae (e.g. *Pardosa spec., Pirata spec*.), harvestmen (e.g. *Phangilium opilio, Opilio saxatilis*) and collembola (e.g. *Folsomia fimetaria, Isotoma notabilis*). Carabid beetles and linyphiid spiders are the most frequently reported groups of ground-dwelling arthropods in potato fields.

Arthropods dwelling in the soil matrix of potato fields include Collembola (e.g. *Mesaphorura krausbaueri, Onychiurus armatus*), pests like wireworms (e.g. *Agriotes lineatus, Agriotes obscurus*) and cutworms (e.g. *Agrotis segetum, Agrotis ypsilon*), millipedes (e.g. *Chromatoiulus unilineatus, Cylindroiulus latestriatus*) and saprophagous as well as predatory mites (e.g. Oribatei *spec*., *Rhodacarellus spec*.). With the exception of soil mites, most species are represented by a limited number of taxa only.

Beneficial arthropods include a number of different taxa of polyphagous predators, aphidophagous predators and parasitoids. Examples of these functional groups are ground beetles (e.g. *Pterostichus melanarius, Harpalus rufipes*), ladybird beetles (e.g. *Coccinella quinquepunctata, Propylea quatuordecimpunctata*), rove beetles (*Aloconota gregaria, Atheta fungi*), clown beetles (e.g. *Hister bisexstriatus*), predatory flies (e.g. *Platypalpus minutus, Dolichopus longicornis*), certain true bug species (e.g. *Anthocoris nemorum*), lacewings (e.g. *Chrysoperla kolthoffi, Chrysopa phyllochroma*), predatory mites (e.g. *Alliphis spec., Arctoseius spec*.), parasitic wasps (e.g. *Aphidius ervi, Aphidius picipes*), tangle-web spiders

(e.g. *Theridion impressum*), linyphiid spiders (e.g. *Erigone atra*) and harvestmen (e.g. *Phangilium opilio, Opilio saxatilis*).

Arthropod diversity in potato fields in Central and Northern Europe is generally low when compared to many other crops (e.g. cereals). Important factors affecting arthropod diversity in potato fields are intensive crop management with frequent and drastic changes of habitat structure due to soil sieving and the formation of raised beds, weed control, and eventually, in conventionally managed fields, the intensive use of insecticides. When compared to cereals such as winter wheat, the late development of potatoes and low levels of post harvest remnants on potato fields may well also have a negative impact on ground- and soil-dwelling (detrivorous) arthropods. Furthermore, adjacent habitats (forests, field boundaries) and abiotic factors (climate, soil type etc.) as well as competition for resources also appear to be important factors affecting the diversity of arthropods in potato fields.

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4 Introduction

Arthropods are important components of all natural and agro-ecosystems. In the agricultural environment they play an important role both as pests and as beneficial organisms and provide food for many farmland birds and mammals (Green 1984; Johnson *et al.* 1992; Poulsen *et al.* 1998).

Since no comprehensive review papers on the arthropod fauna in potato field are currently available in the literature the present review was compiled. The aim of the current review was to identify the arthropod communities and species composition in potato fields. The analysis was restricted to plant and soil dwelling arthropods occurring in Central and Northern European potato fields. Special emphasis was given to beneficial species and factors affecting arthropod abundance under cultivation practice.

The following questions were addressed in the study:

- Which arthropod taxa occur in Central and Northern European potato fields?
- How diverse is the arthropod fauna of Central and Northern European potato fields?
- How diverse is the beneficial arthropod fauna in Central and Northern European potato fields?
- What are the main factors influencing arthropod populations in European potato fields, especially those of beneficial taxa?

5 Material & Methods

5.1 General procedure

A literature search was conducted through the electronic data bases cited below and the RIFCON archive, which contains literature not available in BIOSIS® or other electronic data bases (e.g. older citations, articles in regional journals). Additional references were obtained from reference lists of scientific papers.

5.2 Data sources

A number of electronic data bases were used to conduct the literature search. These data bases included BIOSIS®, Google Scholar® and Google®. Articles written in the following languages were taken into account: English, German, and French (Italian and Spanish proved to be irrelevant for the region this survey focused on). Initial keyword combinations were 'arthropods + potato fields' and 'beneficial organisms + potato'. During the course of the search numerous additional keyword combinations with certain groups of arthropods (e.g. 'Carabidae + potato' or 'spiders + potato') were analysed. No limit was set regarding the publication date of the studies. Additional citations not included in the data bases were collected from reference lists of scientific articles which were found during the literature search.

5.3 Compilation of data

All articles which were identified as potentially relevant were ordered and subjected to a closer examination. Articles which were within the final scope of the literature review were carefully evaluated while all articles which contained no useful information within the scope of the survey were omitted from further analysis.

5.4 General remarks

The literature survey focused on studies conducted in potato fields in central and northern Europe. A number of studies on arthropod communities in potato fields conducted in the United States and Canada were also identified during the literature search. Results from these studies were not considered in the current review. However, a list of studies from non-European countries has been provided in Appendix II.

The current survey no distinction was made between different development stages of arthropods (larvae/nymphs, pupae and adults). Furthermore, strict quantitative data on abundances were not considered because studies were usually not comparable in this respect (e.g. due to varying numbers of traps or varying sampling periods).

6 Results & Discussion

6.1 Number of publications on arthropods in potato fields

In total, 33 relevant publications were identified providing data on one or more groups of arthropods in potato fields of central and northern Europe. Compared to other crops (e.g. cereals) this number is very low. For example, Andersen (1991) reviewed studies on carabid and staphylinid beetles in Norway and revealed three times more investigations conducted in barley than in potato. One of the reasons for this discrepancy may be relatively low species diversity of arthropods in potato fields (see 6.3) and hence low attractiveness of this habitat type to researchers.

Moreover, numbers of publications on certain groups of arthropods distinctly varied which may have different reasons. Ground beetles (Carabidae) for instance are a beautiful group and have attracted the research attention of many professional scientists and amateurs. As a result, a comparatively large number of publications on ground beetles does exist (cf. Table 1). Aphids (Aphidae) are important pests and hence of high economic interest; also for this group several publications are available (cf. Table 1). On the other hand, the majority of mites are not attractive and, in addition, their identification is extremely difficult. In consequence publications on this group are sparse (cf. Table 2).

Section Summary:

33 relevant publications on arthropods in potato fields of central and northern Europe were identified. Numbers of publications on certain groups of arthropods distinctly varied.

6.2 Arthropod taxonomic groups reported in potato fields

In the two tables below, results for insects (Table 1) and other arthropods (Table 2) are presented separately. Families which include beneficial taxa are highlighted in bold text.

Data on 74 arthropod families/superfamilies belonging to 14 different orders/superorders and the 3 classes Insecta (insects, Table 1), Arachnida (arachnids, Table 2) and Diplopoda (millipedes, Table 2) were reported. 41 families/superfamilies including beneficials like polyphagous and aphidophagous predators or parasitoids were reported. More details on the studies cited in Table 1 and Table 2 including species lists are provided in Appendix I.

Table 1 Insect taxa reported for potato fields in Central and Northern Europe

Families which include beneficial taxa are highlighted in bold; Functional Groups: PP = Polyphagous Predators, AP = Aphidophagous Predators, H = Herbivores, PA = Parasitoids, D = Detrivores; Habitat: FO = Foliage, SU = Soil Surface, SO = Soil; Abbreviations of countries according to ISO 3166 (Appendix 3); * Reference list is given below Table 2.

Order	Family	Funct. Group	Habitat	No. of Spec.	Country	Reference*
Coleoptera (Beetles)	**Carabidae** (Ground beetles)	**PP**	SU	8-49	GB,IE,CH,NO, AT,NL,D,FI	1,8,9,19,21,22, 23, 25,28,29
	Coccinellidae (Ladybirds)	**AP**	FO	6	B	5
	Chrysomelidae (Leaf beetles)	H	FO	1	D	7
	Elateridae (Click beetles)	H	SO/FO	3	GB,HR	10,18
	Staphylinidae (Rove beetles)	**PP**	SU	11-21	NO	19
	Histeridae (Clown beetles)	**PP**	SU	4	AT	26
Homoptera	Aphidae (Aphids)	H	FO	3-6	GB,B,D	2,3,4,6,23,30
	Cicadellidae (Leafhoppers)	H	FO	2	PL	31
Heteroptera (True bugs)	Miridae (Cabsid bugs)	H/**PP**	FO	2-19	PL,LV	27,31,33
	Pentatomidae (Stink bugs, Shield bugs)	H	FO	3-5	PL,LV	27,33
	Rhopalidae	H	FO	1	PL	27
	Nabidae (Damsel bugs)	H/**PP**	FO	2	LV	33
	Anthocoridae (Pirate bugs)	**PP**	FO	2	LV	33
	Tingidae (Lace bugs)	H	FO	1	LV	33
	Piesmidae (Ash-grey leaf b.)	H	FO	1	LV	33
	Lygaeidae (Seed bugs)	H	FO	1	LV	33
Diptera (True flies)	**Syrphidae** (Hoverflies)	**AP**	FO	8	B	5
	Dolichopodidae	**PP**	FO	23	D	28
	Empididae	**PP**	FO	41	D	28
	Hybotidae	**PP**	FO	2	D	28
	Microphoridae	**PP**	FO	1	D	28
Neuroptera (Net-winged insects)	**Chrysopidae** (Green lacewings)	**AP**	FO	2-3	B,F	5,13
	Hemerobiidae (Brown lacewings)	**AP**	FO	1	F	13
Collembola (Springtails)	Isotomidae	D	SU	2	EE,GB	12,16
	Entomobryidae	D	SU	1	EE,GB	12,16
	Onychiuridae	D	SO	2	EE	12
	Sminthuridae	D	SU	1	GB	15,16
	Bourletiellidae	D	SU	1	GB	16
	Poduroidae	D	SU	1	GB	16
Lepidoptera (Butterflies and moths)	Noctuidae (Owlet moths)	H	SO/FO	2	HR	18
	Satyridae (Satyrids)	H	FO	3	NL	20
	Hesperiidae (Skipper)	H	FO	1	NL	20
	Pieridae (Whites)	H	FO	2	NL	20
Hymenoptera (Hymenopterans)	**Aphidiidae** (Parasitic wasps)	**PA**	FO	9	B	24
	Braconidae (Parasitic wasps)	**PA**	FO	2	PL	31
	Dryinidae (Parasitic wasps)	**PA**	FO	1	PL	31

Table 2 Other arthropod taxa reported for potato fields in Central and Northern Europe

Families including beneficial taxa are given in bold; Functional Groups: PP = Polyphagous Predators, AP = Aphidophagous Predators, H = Herbivores, PA = Parasitoids, D = Detrivores; Habitat: FO = Foliage, SU = Soil Surface, SO = Soil; Abbreviations of countries according to ISO 3166 (Appendix 3); Links to the relevant references are given below the table

Class	Order/ Superorder	Family/ Superfamily	Funct. Group	Habitat	No. of Spec.	Country	Ref.*
Arachnida (Arachnids)	Opiliones (Harvestmen)	**Phalangiidae**	**PP**	SU	6	GB	11
		Sclerosomatidae	**PP**	SU	1	GB	11
	Araneae (Spiders)	**Linyphiidae** (Sheet weavers)	**PP**	SU	8-41	NL,D	22,28
		Theridiidae (Tangle-web spiders)	**PP**	SU	1-3	CH,D	17,28
		Lycosidae (Wolf spiders)	**PP**	SU	9	D	28
		Thomisidae (Crab spiders)	**PP**	SU	1	D	28
		Gnaphosidae (Ground spiders)	**PP**	SU	1	D	28
		Tetragnathidae (Long-jawed s.)	**PP**	SU	2	D	28
		Clubionidae (Sac spiders)	**PP**	SU	1	D	28
	Sarcoptiformes (Orobatid mites)	Acaroidea	D	SO	6	PL	32
		Glycyphagidae	D	SO	1	PL	32
		Anoetidae	D	SO	1	PL	32
		Oribatei	D	SO	13	PL	32
	Trombidiformes (Trombidiform mites)	Pygmephoridae	D	SO	14	PL	32
		Scutacaridae	D	SO	9	PL	32
		Tarsonemidae	D	SO	1	PL	32
		Eupodidae	D	SO	1	PL	32
		Stigmaeidae	D	SO	1	PL	32
		Nanorchestidae	D	SO	1	PL	32
		Tetranychidae	D	SO/FO	1	PL	32
		Alicorhagiidae	**PP**	SO	1	PL	32
		Rhagidiidae	**PP**	SO	1	PL	32
		Tydeidae	**PP**	SO	1	PL	32
		Bdellidae	**PP**	SO	1	PL	32
		Trombidiidae	**PP**	SO	1	PL	32
	Parasitiformes (Parasitifom mites)	**Eviphididae**	**PP**	SO	2	PL	32
		Ascidae	**PP**	SO	6	PL	32
		Podocinidae	**PP**	SO	1	PL	32
		Pachylaelaptidae	**PP**	SO	1	PL	32
		Halolaelapidae	**PP**	SO	1	PL	32
		Laelaptidae	**PP**	SO	2	PL	32
		Rhodacaridae	**PP**	SO	8	PL	32
		Veigaiaidae	**PP**	SO	2	PL	32
		Ameroseidae	**PP**	SO	1	PL	32
		Parasitidae	**PP**	SO	6	PL	32
		Phytoseiidae	**PP**	SO/FO	1	PL	32
		Macrochelidae	**PP**	SO	2	PL	32
Diplopoda (Millipedes)	Julida (Julid millipedes)	Julidae	D	SO	4	D	14

*References: 1. Armstrong (1995); 2. Broadbent (1946); 3. Jacob (1944); 4. Jansen (2000); 5. Jansen & Warnier (2004); 6. Mattern & Schubert (2002); 7. Langenbruch (1998); 8. O'Sullivan & Gormally (2002); 9. Luka *et al.* (2000); 10. Parker & Howard (2001); 11. Dixon & McKinlay (1989); 12. Kanal (2004); 13. Trouvé *et al.* (2002); 14. Haacker (1968); 15. Shaw & Haughs (1983); 16. Frampton & van den Brink (2002); 17. Nyffeler & Benz (1981); 18. Igrc-Barcic *et al.* (2000); 19. Andersen & Eltun (2000); 20. De Snoo *et al.* (1998); 21. Traugott (1998); 22. Booij & Noorlander (1992); 23. Dixon & McKinlay (1992); 24. Jansen (2005); 25. Kromp (1990); 26. Traugott (2002); 27. Fauvel (1999); 28. Steinborn & Meyer (1994); 29. Kinnunen *et al.* (2001); 30. Karley *et al.* (2003); 31. Bilewicz-Pawinska (1992); 32. Wasylik (1995); 33. Turka (2001) Complete citations are listed in section 7 (References).

Section Summary:

74 families/superfamilies belonging to 14 different orders/superorders and the 3 classes Insecta, Arachnida and Diplopoda are reported in the literature as being present on potato fields in Central and Northern Europe. 41 families/superfamilies included beneficials like polyphagous and aphidophagous predators or parasitoids.

6.3 Species diversity of arthropods in potato fields

6.3.1 Foliage dwelling arthropods

An overview on foliage dwelling arthropods present on potato fields is given in Table 1 and Table 2, details on single species are provided in Appendix 1. Arthropods in the potato canopy can be divided into pests and beneficials. Pests comprise particularly aphids (Aphidae) and the Colorado potato beetle (Chrysomelidae), furthermore certain true bugs (e.g. Miridae), leafhoppers (e.g. Cicadellidae) and butterflies (e.g. Pieridae). Important beneficials are ladybird beetles (Coccinellidae), hoverflies (e.g. Syrphidae), lacewings (e.g. Chrysopidae), parasitic wasps (e.g. Aphidiidae) and, in addition, predatory flies (e.g. Empididae) and certain true bugs (e.g. Anthocoridae)

Due to their economic importance as pest organisms, numerous studies, particularly in Great Britain, were conducted on aphids (e.g. Broadbent 1946; Dixon & McKinlay 1992; Jansen 2000; Mattern & Schubert 2002; Karley *et al.* 2003). Regarding aphid diversity observed in potato fields, the results of these studies are comparable: numbers of different aphid species always varied between three and six (Table 1, Appendix 1). Among the most abundant species were usually *Myzus persicae*, *Macrosiphum euphorbiae* and *Aphis nasturtii* (Broadbent 1946; Broadbent & Tomlin 1982; Jansen 2000; Mattern & Schubert 2002; Karley *et al.* 2003). These species are common not only in potato fields but in a variety of crops.

Extensive data on true bugs (Heteroptera) in European agro-ecosystems (field crops, orchards) was provided by Fauvel (1999). The author reviewed studies on true bugs which were conducted in central, northern and eastern Europe. Taxa representing 19 species were found regularly on potato fields (Appendix 1). Among the most abundant species were *Adelphocoris lineolatus* and *Lygus rugulipennis* which both belong to the family Miridae. According to Fauvel, potato and legume fields have a lower bug species diversity than other crops such as cereals (>25 species) and orchards (60 species).

In a long-term monitoring study over 26 years which had been conducted in Latvia, Turka (2001) observed 30 species of true bugs including both phytophagous pests (e.g. *Lygus rugulipennis*, *Orthotylus flavosparsus*) and polyphagous predators (e.g. *Anthocoris nemorum*, *Orius minutus*) (Table 1, Appendix 1).

De Snoo *et al.* (1998) examined the butterfly fauna (Lepidoptera) of 3 m wide field margins in the western part of the Netherlands. The authors included winter wheat and potato fields in their investigations. In margins of potato fields they found about six common butterfly species among which were the pests species *Pieris napi* and *Pieris rapae* (Appendix 1).

Jansen & Warnier (2004) investigated foliage-dwelling aphid-specific predators in four table potato fields in Wallonia, Belgium. These authors collected data by both visual inspection and by beat sampling. In total, they recorded 16 predatory arthropod taxa including six ladybird beetles (Coccinellidae), eight hoverflies (Syrphidae) and two species of lacewings (Chrysopidae) (Table 1, Appendix 1). The dominant ladybird beetle species were *Coccinella septempunctata* and *Propylea quatuordecimpunctata*. With regard to hoverflies, *Episyrphus balteatus* was prevailing, *Sphaerophoria scripta* and *Syrphus vitripiennis* were subdominant. Lacewings sampled were almost all identified as *Chrysoperla kolthoffi*. In addition, Jansen & Warnier (2004) showed that the species composition of predators varied considerably between different potato fields. As all fields investigated were in similar environments, the authors found themselves unable to provide reasons for the differences between fields.

Trouvé *et al*. (2002) studied lacewings in an agricultural zone near Calais, northern France. They included potato fields and three other field crops as well as apple orchards in their investigations. Sampling methods including vacuum trapping and hand-netting were used. In total, these authors found seven lacewing species of which four were collected in potato fields: three green lacewings (Chrysopidae) and one brown lacewing (Hemerobiidae) (Table 1, Appendix 1). *Chrysoperla kolthoffi* and *Chrysopa phyllochroma* were found to be the two dominant species. The authors suggested that *Chrysopa phyllochroma* can be regarded as a typical species of intensively cultivated crops such as witloof or potato.

Jansen (2005) investigated the diversity of parasitic wasps (Aphidiidae, Hymenoptera) in eleven table potato fields in Belgium. This author recorded nine parasitic wasp species (Appendix 1) among which *Aphidius ervi* and *A. picipes* were most abundant. Additionally, Jansen showed that the aphid *Aulacorthum solani* was the preferred host of several aphid parasitoids (parasitism rate 60-90%). Percentage parasitism of the aphid *Myzus persicae* was also very high (parasitism rate approx. 35%).

Bilewicz-Pawinska (1992) conducted a four-year study on bugs (Heteroptera), leafhoppers (Homoptera) and their parasitoids (parasitic wasps, Hymenoptera) at three different sites in the Warsaw (Poland) region. The author used the sweep-net method to sample bugs and leafhoppers. In total, nine phytophagous bug species were recorded of which only two, *Lygus rugulipennis* and *Campylomma verbasci*, were regarded as potato pests, seriously damaging potato tissues (names of the other species not given). Among the twelve leafhopper species collected during the study, only two species are known to significantly damage potato plants: these are *Empoasca solani* and *Eupteryx atropunctata* (names of the other species not given). Three parasitoid species, parasitizing Heteroptera were also collected (Table 1, Appendix 1): *Peristenus digoneutis* and *Peristenus stygicus* (Braconidae), parasitoids of *Lygus rugulipennis*, and *Aphelopus empoascae* (Dryinidae) which was predominantly found in *Empoasca solani*.

Steinborn & Meyer (1994) studied the predatory arthropod fauna (ground beetles, spiders, predatory flies) of conventionally and organically managed agro-ecosystems at four different sites in northern Germany. With regard to predatory flies (Empidoidea), the authors recorded 67 different species in potato fields. Species observed belonged to the four families Dolichopodidae, Empididae, Hybotidae and Microphoridae. Ten species were dominant; seven of these belonged to the genus *Platypalpus* (e.g. *Platypalpus minutus*, *Platypalpus interstinctus*). The remaining three species were *Dolichopus longicornis*, *Dolichopus acuticornis* and *Tachydromia aemula* (Appendix 1). The majority of species were either those common in various habitats (eurytopic) or those occurring mainly in forests (silvicol). Steinborn & Meyer explained the presence of the latter by forests adjacent to the investigated potato fields.

6.3.2 Arthropods dwelling mainly on the soil surface

An overview on soil surface dwelling arthropods is given in Table 1 and Table 2, details on single species are provided in Appendix 1. The composition of ground dwelling arthropods in potato fields is typically dominated by large ground beetles (Carabidae) (Dixon & McKinlay 1992). As further representatives of Coleoptera, rove beetles (Staphylinidae) and clown beetles (Histeridae) may occur. Ground dwelling spiders which have commonly been found include the families Linyphiidae and Lycosidae. Also harvestmen (Opiliones) were recorded in potato fields. In plant litter at the soil surface collembola (e.g. Isotomidae) usually occur.

Numbers of different taxa of ground beetles in conventionally managed potato fields mostly range between 10 and 20 species (Appendix 1) (Armstrong 1995; Andersen & Eltun 2000; O'Sullivan & Gormally 2002). The generally most abundant species is *Pterostichus melanarius* (Dixon & McKinlay 1992; Armstrong 1995; Kinnunen *et al.* 2001; O'Sullivan & Gormally 2002). Further taxa which usually occur in high abundances are members of the genera *Bembidion* and *Harpalus* (Kinnunen *et al.* 2001; O'Sullivan & Gormally 2002).

Dixon & McKinlay (1992) investigated predatory ground beetles feeding partially or mainly on aphids in potato fields in Scotland. These authors compared unsprayed plots with those treated with an insecticide. Over a period of three years 19 species of carabid beetles (Appendix 1) were recorded. Among these, three species commonly encountered in agro-ecosystems, were dominant: *Trechus quadristriatus, Pterostichus madidus* and *P. melanarius*.

Pterostichus melanarius was also the most abundant species in the study of Steinborn & Meyer (1994) conducted at four sites in northern Germany (Appendix 1). Other abundant species in this area were *Bembidion lampros* and *Platynus dorsalis*. Steinborn & Meyer included both, conventionally and organically managed fields in their investigations. These authors also collected surface dwelling arthropods from cereal and maize fields. A total of 79 species of carabid beetles were found. Fifty-four of these species were either present on most crop types or exclusively on potato fields. The majority of species were considered to be common and occurring in all agro-ecosystems.

A higher carabid diversity distinctly exceeding 20 species is regarded as typical for potato fields which have been managed organically for several years (e.g. Kromp 1990; Traugott 1998). For example, Traugott (1998) collected carabid larvae and adults by pitfall trapping and soil sampling in a small organic potato field in western Austria. Sampling yielded 49 species (Appendix 1) with *Poecilus cupreus*, *Pterostichus melanarius* and *Harpalus rufipes*

as the most abundant species. In a previous study conducted in Austria, the carabid community of two organically and two conventionally farmed potato fields were compared by Kromp (1990). The organically managed fields yielded 37 and 29 carabid species, respectively. Species almost exclusively occurring in organically managed potato fields were *Dyschirius globosus* and *Harpalus aeneus*.

However, conventionally managed potato fields also appear to be able to support a rich and diverse assemblage of ground beetles. Kinnunen *et al.* (2001) investigated carabid beetle communities of conventionally managed potato fields and some other crops at four different sites in Southern Finland. In potato fields these authors recorded up to 33 species of carabids (Appendix 1). Species composition of potato fields at the different Finnish sites was rather similar; *Bembidion quadrimaculatum*, *Bembidion properan*s and *Calathus erratus* showed some preference for potato fields and occurred less frequent in other crops (Kinnunen *et al.* 2001).

Other ground dwelling representatives of polyphagous predatory Coleoptera occasionally found in potato fields are rove beetles (Staphylinidae) and clown beetles (Histeridae) (Table 1). Andersen & Eltun (2000) conducted a long-term field experiment including crop rotation in south-east Norway and found between 11 and 21 rove beetle species on various potato plots. The most abundant species of rove beetles were *Aloconota gregaria*, *Atheta fungi* and *Tachinus signatus* (Appendix 1). Traugott (2002) investigated the histerid beetle community of a potato field in Tyrol, Austria. The field had been cultivated organically for several years. Histerid beetles which are regarded as typical dwellers of transient highly dynamic habitats were collected over one year by pitfall trapping and soil sampling. Traugott found four different species among which *Hister bisexstriatus* was by far the most abundant (98.7%). The other species which all belonged to the genus *Margarinotus* contributed only a few percent to the total of collected individuals.

Regarding ground dwelling spiders, the family Linyphiidae is considered to dominate the spider fauna in European field crops (Nyffeler & Sunderland 2003). In a three-year study Booij & Noorlander (1992) investigated the predator fauna (carabids, staphylinids, spiders) of six field crops in the Netherlands. Each crop was cultivated in three different systems (conventional, integrated, and organic). Ground dwelling predators were caught by pitfall trapping. In potato plots, Booij & Noorlander recorded between eight and nine species of linyphiid spiders. Unfortunately, the authors did not provide species names in their article.

In a study conducted in Northern Germany, Steinborn & Meyer (1994) found 41 taxa of linyphiid spiders in organically and conventionally managed potato fields (Table 2, Appendix 1). *Erigone atra*, a species capable to rapidly colonize disturbed habitats, proved to be the most common. Regarding abundance only four species of linyphiid spiders contributed more than 90% to the total number of individuals during the study. These were *Bathyphantes gracilis*, *Erigone atra*, *Oedothorax apicatus* and *Oedothorax fuscus*. The second most diverse group reported in the Steinborn & Meyer survey was the spider family Lycosidae with nine different taxa belonging to the three genera *Pardosa*, *Pirata* and *Trochosa* (Table 2, Appendix 1).

Dixon & McKinlay (1989) investigated harvestmen (Opiliones) in potato fields near Edinburgh, Scotland. Over the study period of three years, the authors caught seven different species by pitfall trapping (Table 2, Appendix 1). *Phangilium opilio* was dominant and *Opilio saxatilis* was the second most frequently trapped species.

Kanal (2004) conducted a survey on collembola in potato fields in Southern Estonia. Collembola were captured by taking soil cores and subjected to McFadyen extraction. Kanal determined three dominant species that occurred mainly in plant litter and in the upper soil layer (hemiedaphic): *Folsomia fimetaria*, *Isotoma notabilis* and *Lepidocyrtus cyaneus* (Appendix 1).

6.3.3 Arthropods dwelling within the soil matrix

An overview on soil dwelling arthropods is given in Table 1 and Table 2, details on single species are provided in Appendix 1. The range of arthropods dwelling within the soil matrix of potato fields is generally poor and typically includes a small number of taxa, each represented by only a few species. Higher species diversity may only be expected in case of soil mites (see below). Important groups of soil dwelling arthropods are Collembola (e.g. Onychiuridae), wireworms (Elateridae), cutworms (Noctuidae), millipedes (Julidae) and saprophagous as well as predatory mites (e.g. Oribatei, Rhodocaridae).

Collembola are partly soil dwelling; Kanal (2004) recorded two dominant collembola species of deeper soil layers (euedaphic) in potato fields in Estonia: *Mesaphorura krausbaueri* and *Onychiurus armatus* (Table 1Appendix 1).

The soil harbours important potato pests such as wireworms, the larvae of click beetles (Elateridae) and cutworms, the larvae of owlet moths (Noctuidae) (Table 1, Appendix 1). In potato fields in Great Britain, three species of wireworms have been found (Parker & Howard 2001): *Agriotes lineatus*, *Agriotes obscurus*, *Agriotes sputator*. Igrc-Barcic *et al.* (2000) reported the same three species of *Agriotes* in seed potato fields in Croatia. Furthermore they found two species of cutworms: *Agrotis segetum* and *Agrotis ypsilon*.

Haacker (1968) investigated detrivorous millipedes in various habitats in the Rhine-Main area of south-western Germany. Four species of the Julidae family were regularly found on potato fields: *Chromatoiulus unilineatus*, *Cylindroiulus latestriatus*, *Cylindroiulus londinensis* and *Schizophyllum sabulosum* (Table 2, Appendix 1).

Wasylik (1995) investigated communities of saprophagous and predatory soil mites in potato fields at three different sites in Poland. Besides species composition, also seasonal dynamics and vertical distribution were investigated. Wasylik identified about 50 and 40 different species of saprophagous and predatory mites, respectively (Table 12, Appendix 1). The most abundant genera of saprophagous mites were *Siteroptes* and *Oribatei*; among predatory mites the genera *Alliphis* and *Rhodacarellus* occurred most frequently. Only a few species were dominant whereas the majority of taxa occurred only occasionally.

Section Summary:

Arthropods dwelling on potato foliage can be divided into pests and beneficials. Pests include aphids (e.g. *Myzus persicae*, *Macrosiphum euphorbiae*), the Colorado potato beetle (*Leptinotarsa decemlineata*), certain true bugs (e.g. *Adelphocoris lineolatus, Lygus rugulipennis*), leafhoppers (e.g. *Empoasca solani*, *Eupteryx atropunctata*) and butterflies (e.g. *Pieris napi*, *Pieris rapae*). Important beneficials are ladybird beetles (e.g. *Coccinella septempunctata*, *Propylea quatuordecimpunctata*), hoverflies (e.g. *Episyrphus balteatus*, *Syrphus vitripiennis*), lacewings (e.g. *Chrysoperla kolthoffi*, *Chrysopa phyllochroma*),

parasitic wasps (e.g. *Aphidius ervi*, *Aphidius picipes*), predatory flies (e.g. *Platypalpus minutus*, *Dolichopus longicornis*) and certain true bugs (e.g. *Anthocoris nemorum, Orius minutus*). Besides true bugs and predatory flies, the majority of foliage dwelling taxa is usually represented by less than 10 species.

Ground dwelling arthropods in potato fields include ground beetles (e.g. *Pterostichus melanarius, Harpalus rufipes*), rove beetles (e.g. *Aloconota gregaria*, *Atheta fungi*), clown beetles (*Hister bisexstriatus*, *Margarinotus spec.*) spiders of the families Linyphiidae (e.g. *Erigone atra, Bathyphantes gracilis*) and Lycosidae (e.g. *Pardosa spec.*, *Pirata spec.*), harvestmen (e.g. *Phangilium opilio*, *Opilio saxatilis*) and collembola (e.g. *Folsomia fimetaria*, *Isotoma notabilis*). With regard to species diversity, carabid beetles and linyphiid spiders are the most prevailing groups of ground dwelling arthropods in potato fields.

Arthropods dwelling in the soil matrix of potato fields include Collembola (e.g. *Mesaphorura krausbaueri*, *Onychiurus armatus*), pests like wireworms (e.g. *Agriotes lineatus*, *Agriotes obscurus*) and cutworms (e.g. *Agrotis segetum*, *Agrotis ypsilon*), Millipedes (e.g. *Chromatoiulus unilineatus*, *Cylindroiulus latestriatus*) and saprophagous as well as predatory mites (e.g. *Oribatei spec., Rhodacarellus spec.*). Most taxa are represented by only a few species; higher species diversity may only be expected in case of soil mites.

6.4 Beneficial arthropods in potato fields

Ground beetles (Carabidae, e.g. *Pterostichus melanarius, Harpalus rufipes*) feed on a variety of potato pests including aphids, slugs and representatives of Diptera and Lepidoptera (Holland & Luff 2000). Predating ground beetle larvae (e.g. *Amara spec.*, *Bembidion spec.*, *Calathus spec.*) are also regarded as fundamental in the regulation of certain crop pests (Traugott 1998). Larvae of ladybird beetles (Coccinellidae, e.g. *Coccinella quinquepunctata, Propylea quatuordecimpunctata*) as well as adults are considered important and efficient predators of aphids in commercial table potato fields (Jansen & Warnier 2004). Rove beetles (Staphylinidae) are polyphagous predators and capable, like ground beetles, to markedly reduce insect pests in conventional agricultural fields. Examples of rove beetles are *Aloconota gregaria*, *Atheta fungi* and *Tachinus signatus* (Andersen & Eltun 2000). Clown beetles (Histeridae) feed particularly on dipterous pests. According to Traugott (2002) these beetles, particularly abundantly occurring species such as *Hister bisexstriatus*, have the potential to become an important part of the predator guild in potato fields.

Turka (2001) observed the predatory *Anthocoris nemorum* as one of the most regular occurring true bug species in potato fields in Latvia. *Anthocoris nemorum* is known to feed particularly on aphids, mites and small caterpillars (Fauvel 1999).

Steinborn & Meyer (1994) found high abundances of predatory flies (Empidoidea, e.g. *Platypalpus minutus*, *Dolichopus longicornis*, *Tachydromia aemula*) in potato fields and other crops and attributed a considerable potential in the regulation of pest populations to these organisms. The larvae of lacewings such as *Chrysoperla kolthoffi* or *Chrysopa phyllochroma* (Chrysopidae) are predators of a wide range of prey, particularly aphids (Trouvé *et al.* 2002).

According to Kanal (2004) collembola suppress pathogenic nematodes. Predatory mites (e.g. *Alliphis spec.*, *Arctoseius spec.*) are considered by Wasylik (1995) to be important antagonists of soil dwelling potato pests.

Parasitic Hymenoptera (e.g. *Aphidius ervi*, *Aphidius picipes*) are key natural enemies of aphids in potato fields (Jansen 2005). Bilewicz-Pawinska (1992) demonstrated that members of the families Braconidae and Dryinidae (e.g. *Peristenus stygicus*, *Aphelopus empoascae*) are able to considerably reduce numbers of plant sucking bugs and leafhoppers.

Tangle-web spiders (Theridiidae) like *Theridion impressum* were observed to feed predominantly on aphids in potato fields in Switzerland (Nyffeler & Benz 1981). Small linyphiid spiders (e.g. *Erigone atra*) and harvestmen (e.g. *Phangilium opilio, Opilio saxatilis*) are also important predators of aphids in potato fields (Dixon & McKinlay 1989; Nyffeler & Sunderland 2003).

Lipa *et al.* (1998) provided an overview of predators and parasitoids of the Colorado potato beetle (*Leptinotarsa decemlineata*) in Europe and the United States. In total, almost 300 arthropod species are regarded as predators or parasites of various stages of this pest. Hough-Goldstein *et al.* (1993) gave detailed information on the major biological control agents (natural enemies) of the Colorado potato beetle in the United States and Europe. Several of these taxa (e.g. members of the family Pentatomidae) do not occur naturally in Europe. They were introduced as biocontrol agents in order to suppress Colorado beetle populations but failed to become established in Europe. As a likely reason the authors proposed that many of the taxa originated from tropical or subtropical areas and have difficulties in surviving winter in temperate regions.

Section Summary:
Beneficial arthropods include a number of different taxa of polyphagous predators, aphidophagous predators and parasitoids. Examples of those functional groups are ground beetles (e.g. *Pterostichus melanarius, Harpalus rufipes*), ladybird beetles (e.g. *Coccinella quinquepunctata, Propylea quatuordecimpunctata*), rove beetles (*Aloconota gregaria*, *Atheta fungi*), clown beetles (e.g. *Hister bisexstriatus*), predatory flies (e.g. *Platypalpus minutus*, *Dolichopus longicornis*), certain true bug species (e.g. Anthocoris nemorum), lacewings (e.g. *Chrysoperla kolthoffi, Chrysopa phyllochroma*), predatory mites (e.g. *Alliphis spec.*, *Arctoseius spec.*), parasitic wasps (e.g. *Aphidius ervi*, *Aphidius picipes*), tangle-web spiders (e.g. *Theridion impressum*), linyphiid spiders (e.g. *Erigone atra*) and harvestmen (e.g. *Phangilium opilio, Opilio saxatilis*).

6.5 Arthropod diversity in potato fields in comparison with other crops

Compared to many other crops (e.g. cereals), arthropod diversity in potato fields in Central and Northern European is rather low. For instance, Steinborn & Meyer (1994) recorded almost twice as many species of ground beetles in cereal fields in Northern Germany than in potato fields. In the Netherlands, Booij & Noorlander (1992) observed greater carabid diversity in wheat than in potato or vegetables. Additionally, carabid abundance was much higher in wheat than in potato which was found to be the case in conventional, integrated and organic fields. According to Fauvel (1999) diversity of true bugs (Heteroptera) was greater in cereals than in potato fields. However, during a period from 1974 to 1989 Turka

(2001) recorded distinctly more species of true bugs in potato fields than in cereals or in sugar beet. Frampton & van den Brink (1992) showed that diversity and abundance of collembola was higher in winter-sown cereals than in spring sown crops such as potato.

Section Summary:
Arthropod diversity in potato fields in Central and Northern Europe is generally low as compared to many other crops (e.g. cereals).

6.6 Factors affecting arthropod diversity in potato fields

Crop management

Cultivation of potato is associated with frequent and drastic changes of habitat structure due to soil sieving and formation of raised beds. Such intensive management generally discriminates against organisms with long life-cycles, e.g. large ground beetles (Carabidae) and wolf spiders (Lycosidae) (Cole *et al.* 2005). Taxa with the capability to cope with these extreme conditions are mainly those being classified as invasive species with high reproductive capacities (ecological r-strategy). For example, bugs (e.g. *Lygus rugulipennis*) are able to rapidly recolonize disturbed habitats (Bilewicz-Pawinska 1992).

Tillage practised in organic farming (e.g. rotary cultivation) is thought to be detrimental to ground dwelling carabids (Armstrong 1995). According to Luka *et al.* (2000) the preceding crop also has an influence on the composition of the carabid fauna in potato fields. These authors suggest that winter wheat and rape as precedent crops increase both carabid abundance and species diversity.

Weed removal, either by mechanical methods or herbicides, is expected to negatively affect abundance and diversity of ground dwelling predators such as carabid and staphylinid beetles and spiders (Booij & Noorlander 1992). However, Steinborn & Meyer (1994) revealed conspicuously even greater diversity of spiders (Aranae) in conventionally than in organically managed potato fields.

The impact of plant protection products on the arthropod fauna in potato fields appears to be controversial. While Luka *et al.* (2000) suggested a direct negative influence of insecticides on ground beetles, Armstrong (1995) found more carabids and greater species diversity in conventionally grown seed potato fields than in organic potato. According to the author, an impact of insecticides on carabids is to be expected only early in the season when vegetation cover is sparse. Bilewicz-Pawinska (1992) found only slight impact of insecticides used for the control of Colorado potato beetle on populations of herbivorous bugs (*Lygus rugulipennis*, *Campylomma verbasci*) and leafhoppers (*Empoasca solani*, *Eupteryx atropunctata*). However, Hough-Goldstein *et al.* (1993) suggested that broad-spectrum insecticides hinder the efficacy of arthropod predator populations in commercial potato fields. According to Frampton & van den Brink (1992) high pesticide inputs in sugar beet and potato fields are responsible for reduced diversity and abundance of collembola compared to winter-sown cereal fields. De Snoo *et al.* (1998) showed that in unsprayed margins of potato fields abundances of certain butterfly species (e.g. *Maniola jurtina*, *Pieris rapae*) were significantly higher than in margins treated with herbicides and insecticides.

Two additional factors related to crop management can influence arthropod diversity and abundance and should be taken into account. Firstly, the late crop development in potatoes probably causes unfavourable conditions for ground dwellers because protection by the vegetation cover is lacking for prolonged periods and microclimatic conditions are temporarily adverse (Booij & Noorlander 1992). Secondly, plant remains which are of particular importance for detrivorous taxa are generally available only in low quantities in potato fields as compared to other crop remnants such as stubbles in cereal fields (Kanal 2004).

Other factors

Several authors have suggested that both structure and composition of land adjacent to potato fields influences ground beetle abundance and diversity within crop fields (Steinborn & Meyer 1994; Kinnunen *et al.* 2001; O'Sullivan & Gormally 2002). According to Steinborn & Meyer (1994), forests in the vicinity of potato fields may increase the occurrence of forest species. Kinnunen *et al.* (2001) propose an effect of adjacent forests, ditches and grassy banks on the community structure of carabids in potato fields. O'Sullivan & Gormally (2002) suppose that legume fields close to their studied potato fields produced an increase of species diversity and abundance in carabids.

Sotherton (1984) stressed the importance of field boundaries as over-wintering sites for polyphagous predators. It is generally accepted that field margins provide refuge for beneficial organisms, e.g. parasitoids and predators, which can disperse into the field from their shelter habitat (e.g. Stechmann & Zwölfer 1988, Molthan & Ruppert 1989, Canters & Tamis 1999).

Environmental conditions can also influence arthropod abundance. Kanal (2004) found a positive influence of precipitation on collembola populations. Bilewicz-Pawinska (1992) reported a positive influence of high temperatures and low rainfall on growth of plant sucking bug and leafhopper populations. However, Broadbent (1946) did not find any correlation between aphid diversity and environmental conditions in Great Britain.

Crop development might influence ground dwellers. Armstrong (1995) investigated ground beetles in conventional and organic potato fields. He concluded that carabids profit from the denser canopy of conventional potato fields as it provides more humid and shady conditions on the soil surface compared to organic potato fields.

Soil type may also affect arthropod diversity and abundance. According to Parker & Howard (2001) wireworms are more common in potato fields on heavy alluvial soils with high soil moisture than in those on light and dry sandy soils. The results presented by Steinborn & Meyer (1994) suggest that soil type (Podzol, Luvisol) affects the fauna of carabids, spiders and flies more than the intensity of field management (conventional, biological) or the crop (potato, cereals, maize).

Competition for prey between predatory arthropods can suppress certain groups. Andersen & Eltun (2000) explained the decline of a staphylinid beetle population by an increase of larger and more competitive carabid beetles. In potato fields in Belgium, Jansen & Warnier (2004) recorded the Asian ladybeetle *Harmonia axyridis*. Such exotic species may out-compete indigenous species which eventually can result in a decrease of diversity (Jansen & Warnier 2004).

Section Summary:

Important factors affecting arthropod diversity in potato fields are intensive crop management with frequent and drastic changes of habitat structure due to soil sieving and the formation of raised beds, weed control, and eventually, in conventionally managed fields, the intensive use of insecticides. When compared to cereals such as winter wheat, the late development of potatoes and low levels of post harvest remnants on potato fields may well also have a negative impact on ground- and soil-dwelling (detrivorous) arthropods. Furthermore, adjacent habitats (forests, field boundaries) and abiotic factors (climate, soil type etc.) as well as competition for resources also appear to be important factors affecting the diversity of arthropods in potato fields.

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8 Appendix 1: Studies on arthropods in central and northern European potato fields

Author	Country	Type of potato	Sampling method	Family (No. of species) Species		Comments
Armstrong (1995)	Great Britain (Northern Scotland)	seed potato, organic potato	pitfall trapping	Carabidae (8-20) *Agonum dorsale* *Amara apricaria* *Amara aulica* *Amara bifrons* *Amara eurynota* *Amara familiaris* *Amara plebeja* *Asaphidion flavipes* *Bembidion aeneum* *Bembidion lampros* *Bembidion tertracolon* *Calathus fuscipes* *Calathus melanocephalus*	*Clivina fossor* *Harpalus aeneus* *Harpalus rufipes* *Loricera pilicornis* *Nebria brevicollis* *Nitiophilus biguttatus* *Patrobus atrorufus* *Pterostichus melanarius* *Pterostichus niger* *Pterostichus oblongopunctatus* *Pterostichus strennuus* *Trechus micros* *Trechus quadristriatus* *Synuchus nivalis*	
Broadbent (1946)	Central Great Britain	seed potato	leaf counts, sticky traps	Aphidae (4) *Aphis nasturtii* *Aulacorthum solani* *Macrosiphum euphorbiae* *Myzus persicae*		
Jacob (1944)	Northern Great Britain	seed potato	leaf counts	Aphidae (4) *Aphis nasturtii* *Aulacorthum solani* *Macrosiphum euphorbiae* *Myzus persicae*		
Jansen (2000)	Belgium	table potato	leaf counts	Aphidae (5) *Aphis fabae* *Aphis nasturtii* *Aulacorthum solani* *Macrosiphum euphorbiae* *Myzus persicae*		
Jansen & Warnier (2004)	Belgium	table potato	visual inspection, beating	Coccinellidae (6) *Adalia bipunctata* *Adalia tenpunctata* *Coccinella quinquepunctata* *Coccinella septempunctata* *Harmonia axyridis* *Propylea quatuordecimpunctata*	Syrphidae (8) *Episyrphus balteatus* *Melanostoma mellinum* *Melanostoma scalare* *Melliscaevva cinctella* *Metasyrphus corollae* *Platycheirus albimanus* *Sphaerophoria scripta* *Syrphus vitripiennis*	

				Chrysopidae (2) *Chrysopa perla* *Chrysoperla kolthoffi*		
Mattern & Schubert (2002)	East Germany	table potato, GM potato	leaf counts	Aphidae (6) *Aphis fabae* *Aphis frangulae* *Aphis nasturtii* *Cavariella aegopodium* *Macrosiphum euphorbiae* *Myzus persicae*		
Langenbruch (1998)	Germany	not specified		Chrysomelidae (1) *Leptinotarsa decemlineata*		review on Colorado potato beetle without own investigations
O'Sullivan and Gormally (2002)	West Ireland	conventional and organic potato	pitfall trapping	Carabidae (17) *Abax parallelepipedus* *Agonum dorsale* *Agonum muelleri* *Amara plebeja* *Asaphidion flavipes agg.* *Bembidion bruxellense* *Carabus granulatus* *Carabus nemoralis*	*Clivina fossor* *Harpalus rufipes* *Loricera pilicornis* *Nebria brevicollis* *Pterostichus niger* *Pterostichus nigrita agg.* *Pterostichus madidus* *Pterostichus melanarius* *Stomis pumicatus*	
Luka et al. (2000)	Switzerland	organic potato	pitfall trapping	Carabidae (12) *Agonum muelleri* *Amara plebeja* *Bembidion lampros* *Bembidion properans* *Bembidion quadrimaculatum* *Clivina fossor*	*Harpalus rufipes* *Microlestes minutulus* *Nebria brevicollis* *Poecilus cupreus* *Pterostichus anthracinus* *Pterostichus melanarius*	
Parker & Howard (2001)	Great Britain	not specified		Elateridae (3) *Agriotes lineatus* *Agriotes obscurus* *Agriotes sputator*		review on wireworms without own investigations
Dixon & McKinlay (1989)	Great Britain (Scotland)	cv. Maris Piper (table potato)	pitfall trapping	Phalangiidae (6) *Mitopus morio* *Oligolophus tridens* *Opilio parietinus* *Opilio saxatilis* *Paroligolophus agrestis* *Phalangium opilio*	Sclerosomatidae (1) *Leiobunum rotundum*	

Kanal (2004)	Estonia	not specified	McFadyen extraction	Isotomidae (2) *Folsomia fimetaria* *Isotoma notabilis*	Entomobryidae (1) *Lepidocyrtus cyaneus*	
				Onychiuridae (2) *Mesaphorura krausbaueri* *Onychiurus armatus*		
Trouvé et al. (2002)	Northern France	not specified	suction trap, yellow traps, vacuum trapping, hand netting	Chrysopidae (3) *Chrysopa phyllochroma* *Chrysoperla carnea* *Chrysoperla kolthoffi*	Hemerobiidae (1) *Micromus variegatus*	
Haacker (1968)	Central Germany	not specified	quadrate sampling, pitfall trapping	Julidae (4) *Chromatoiulus unilineatus* *Cylindroiulus latestriatus* *Cylindroiulus londinensis* *Schizophyllum sabulosum*		possibly additional taxa also collected in potato fields (vague description)
Shaw & Haughs (1983)	Great Britain (Northern Scotland)	cv. Kerr's Pink, cv. Maris Piper (table potato)	visual examination	Sminthuridae (1) *Sminthurus viridis*		
Frampton & van den Brink (2002)	Central Great Britain	not specified	suction sampling	Sminthuridae (1) *Sminthurinus elegans*	Bourletiellidae (1) *Deuterosminthurus spec.*	crop rotation system, possibly not all taxa collected strictly in potato
				Poduroidae (1) Species not identified	Isotomidae (2) *Isotoma notabilis* *Isotoma viridis*	
				Entomobryidae (1) *Lepidocyrtus spec.*		

Nyffeler & Benz (1981)	Switzerland	not specified	observation, catching with beaker	Theridiidae (1) *Theridion impressum*		vague habitat descriptions, further taxa possibly also collected in potato fields
Igrc-Barcic et al. (2000)	Croatia	cv. Desiree (seed potato)	tuber investigation	Elateridae (3) *Agriotes lineatus* *Agriotes obscurus* *Agriotes sputator*	Noctuidae (2) *Agrotis segetum* *Agrotis ypsilon*	crop rotation system
Andersen & Eltun (2000)	South-east Norway	early potato / late potato	pitfall trapping	Carabidae (10-16) *Bembidion lampros* *Bembidion quadrimaculatum* *Calathus melanocephalus* *Clivina fossor* *Trechus secalis*	Staphylinidae (11-21) *Aloconota gregaria* *Atheta fungi* *Tachinus signatus*	only dominant species given
de Snoo et al. (1998)	The Netherlands	not specified	transect method	Satyridae (3) *Coenonympha pamphilus* *Lasiommata megera* *Maniola jurtina*	Hesperiidae (1) *Thymelicus lineola*	data presented imprecise; possibly additional species found
				Pieridae (2) *Pieris napi* *Pieris rapae*		
Traugott (1998)	Austria	organic potato field	pitfall trapping, soil sampling (larvae)	Carabidae (49) *Abax parallelepipedus* *Agonum muelleri* *Agonum sexpunctatum* *Amara aenea* *Amara aulica* *Bembidion lampros* *Bembidion properans* *Calathus fuscipes* *Calathus melanocephalus* *Carabus cancellatus* *Carabus coriaceus* *Carabus granulatus* *Carabus hortensis*	*Carabus nemoralis* *Clivina fossor* *Dyschirius globosus* *Harpalus rufipes* *Loricera pilicornis* *Nebria brevicollis* *Notiophilus palustris* *Platynus dorsalis* *Poecilus cupreus* *Poecilus versicolor* *Pterostichus melanarius* *Pterostichus oblongopunctatus*	further species with low abundances not given

Booij & Noorlander (1992)	The Netherlands	conventional, integrated and organic potato	pitfall trapping	Carabidae (9-12) *Agonum muelleri* *Bembidion properans* *Pterostichus melanarius*	Linyphiidae (8-9) no detailed information on species	detailed information on species found is lacking
Dixon & McKinlay (1992)	Great Britain (Scotland)	cv. Maris Piper (table potato)	leaf counts, pitfall trapping	Aphidae (3) *Aulacorthum solani* *Macrosiphum euphorbiae* *Myzus persicae*	Carabidae (19) *Agonum dorsale* *Amara apricaria* *Bembidion femoratum* *Bembidion guttula* *Bembidion lampros* *Bembidion obtusum* *Bembidion tetracolum* *Calathus fuscipes* *Calathus melanocephalus* *Clivina fossor* *Harpalus aeneus* *Harpalus rufipes* *Nebria brevicollis* *Notiophilus palustris* *Pterostichus adstrictus* *Pterostichus madidus* *Pterostichus melanarius* *Pterostichus niger* *Trechus quadristriatus*	
Jansen (2005)	Belgium	table potato	leaf samples with aphids	Aphidiidae (9) *Aphidius ervi* *Aphidius matricariae* *Aphidius picipes* *Binodoxys angelicae*	*Diaeretiella rapae* *Praon abjectum* *Praon gallicium* *Praon volucre* *Toxares deltiger*	
Kromp (1990)	Austria	organically / conventionally managed potato	pitfall trapping	Carabidae (48) *Amara consularis* *Bembidion lampros* *Bembidion quadrimaculatum* *Calathus fuscipes* *Calathus melanocephalus* *Carabus cancellatus* *Carabus scheidleri* *Dyschirius globosus*	*Harpalus aeneus* *Harpalus rufipes* *Loricera pilicornis* *Platynus dorsalis* *Poecilus cupreus* *Poecilus versicolor* *Pterostichus melanarius* *Trechus quadristriatus*	further species with low abundances not given
Traugott (2002)	Austria	organic potato	pitfall trapping, soil sampling	Histeridae (4) *Hister bisexstriatus* *Margarinotus carbonarius* *Margarinotus purpurascens* *Margarinotus stercorarius*		

Fauvel (1999)	Poland, France and others	not specified		Miridae (13) *Adelphocoris lineolatus* *Leptopterna dolobrata* *Lygus gemellatus* *Lygus pratensis* *Lygus punctatus* *Lygus rugulipennis* *Notostira erratica* *Orthotylus flavosparsus* *Stenodema calcaratum* *Stenodema laevigatum* *Stenodema virens* *Trigonotynus pulchellus* *Trigonotynus ruficornis*	Pentatomidae (5) *Carpocoris fuscispinus* *Dolycoris baccarum* *Eurydema oleraceum* *Eurydema ornatum* *Holcostethus vernalis*	Rhopalidae (1) *Myrmus miriformis*	review paper without own investigations

Steinborn & Meyer (1994)	Northern Germany	organically / conventionally managed potato	pitfall trapping, photo eclectors	Carabidae (28-31) *Acupalpus micans* *Acupalpus muelleri* *Agonum pelidnum* *Amara aenea* *Amara apricaria* *Amara aulica* *Amara bifrons* *Amara consularis* *Amara familiaris* *Amara fulva* *Amara similata* *Amara spreta* *Asaphidion flavipes* *Badister bullatus* *Bembidion lampros* *Bembidion obtusum* *Bembidion tetracolum* *Broscus cephalotes* *Calathus erratus* *Calathus fuscipes* *Calathus melanocephalus* *Calathus ochropterus* *Carabus auratus* *Carabus cancellatus* *Carabus convexus* *Carabus coriaceus* *Carabus granulatus* *Carabus hortensis* *Carabus nemoralis* *Clivina fossor* *Harpalus affinis* *Harpalus rufibarbis* *Harpalus rufipes* *Harpalus tardus* *Lasiotrechus discus* *Loricera pilicornis* *Nebria brevicollis* *Notiophilus biguttatus* *Platynus obscurus* *Platynus assimilis* *Platynus dorsalis* *Poecilus cupreus* *Poecilus versicolor* *Pterostichus melanarius* *Pterostichus niger* *Pterostichus nigrita* *Pterostichus oblongopunctatus* *Pterostichus strenuus* *Pterostichus vernalis* *Stomis pumicatus* *Syntomus foveatus* *Synuchus vivalis* *Trechoblemus micros* *Trechus quadristriatus*	Linyphiidae (41) *Agyneta conigera* *Allomengea scopigera* *Allomengea vidua* *Araeoncus humilis* *Bathyphantes gracilis* *Bathyphantes approximates* *Bathyphantes parvulus* *Dicymbium nigrum* *Dicymbium tibiale* *Diplocephalus cristatus* *Diplocephalus latifrons* *Diplostyla concolor* *Erigone atra* *Erigone dentipalpis* *Erigone longipalpis* *Erigone vagans* *Lepthyphantes flavipes* *Lepthyphantes pallidus* *Lepthyphantes tenuis* *Lophomma punctatum* *Maso sundevalli* *Meioneta rurestris* *Micrargus herbigradus* *Microlinyphia pusilla* *Oedothorax apicatus* *Oedothorax fuscus* *Oedothorax gibbosus* *Oedothorax retusus* *Ostearius melanopygius* *Pelecopsis radicicola* *Pelecopsis parallela* *Pocadicnemis juncea* *Porrhomma pygmaeum* *Porrhomma egeria* *Savignya frontata* *Stemonyphantes lineatus* *Tiso vagans* *Walckenaeria atrotibialis* *Walckenaeria dysderoides* *Walckenaeria furcillata* *Walckenaeria stylifrons*	

				Lycosidae (9) *Pardosa agricola* *Pardosa amentata* *Pardosa pullata* *Pardosa palustris* *Pardosa monticola* *Pirata hygrophilus* *Pirata piraticus* *Trochosa ruricola* *Trochosa terricola*	Tetragnathidae (2) *Pachygnatha degeeri* *Pachygnatha clercki*	
				Theridiidae (3) *Achaearanea riparia* *Episinus truncates* *Robertus lividus*	Clubionidae (1) *Clubiona neglecta*	
				Thomisidae (1) *Oxyptila simplex*	Gnaphosidae (1) *Micaria pulicaria*	
				Microphoridae (1) *Microphor holosericeus*	Hybotidae (2) *Bicellaria sulcata* *Crossopalpus humilis* *Crossopalpus nigritellus*	

				Empididae (41) *Dolichocephala irrorata* *Drapetis pusilla* *Empis caudatula* *Empis livida* *Empis nuntia* *Hilara chorica* *Hilara cingulata* *Hilara clypeata* *Hilara flavipes* *Hilara litorea* *Hilara lurida* *Hilara obscura* *Phyllodromia melanocephala* *Platypalpus annulatus* *Platypalpus articulatoides* *Platypalpus articulatus* *Platypalpus australominutus* *Platypalpus calceatus* *Platypalpus cothurnatus* *Platypalpus excisus* *Platypalpus interstinctus* *Platypalpus longicornis* *Platypalpus longiseta* *Platypalpus maculipes* *Platypalpus minutus* *Platypalpus pallidicornis* *Platypalpus pallidiventris* *Platypalpus pallipes* *Platypalpus praecinctus* *Platypalpus pseudofulvipes* *Platypalpus pulicarius* *Platypalpus rapidus* *Platypalpus stabilis* *Platypalpus strigifrons* *Rhamphomyia sulcata* *Tachydromia aemula* *Tachydromia annulimana* *Tachydromia arrogans* *Tachydromia terricola* *Tachydromia umbrarum* *Tachypeza nubila*	Dolichopodidae (23) *Chrysotimus molliculus* *Chrysotus cilipes* *Chrysotus gramineus* *Chrysotus neglectus* *Dolichopus acuticornis* *Dolichopus agilis* *Dolichopus cilifernoratus* *Dolichopus festivus* *Dolichopus linearis* *Dolichopus longicornis* *Dolichopus occultus* *Dolichopus pennatus* *Dolichopus plumipes* *Dolichopus simplex* *Dolichopus trivialis* *Dolichopus ungulatus* *Hercostomus praeceps* *Medetera jacula* *Sciapus lobipes* *Sciapus longulus* *Sciapus platypterus* *Sciapus wiedemanni* *Xanthochlorus tenellus*	
Turka (2001)	Latvia	not specified	sweep-netting, beating sheet	Nabidae (2) *Nabis ferus* *Nabis rugosus*	Anthocoridae (2) *Anthocoris nemorum* *Orius minutus*	
				Miridae (19) *Adelphocoris lineolatus* *Adelphocoris annulicornis* *Calocoris norvegicus* *Campylomma verbasci* *Charagochilus gullenhali* *Chlamydatus pullus* *Leptoterna dolobrata* *Lygus lucorum* *Lygus pratensis*	*Lygus punctatus* *Lygus rugulipennis* *Notostira laevigata* *Orthops kalmi* *Orthotylus flavosparsus* *Plagiognathus arbustorum* *Plagiognathus chrysanthemi* *Stenodema calcaratum* *Stenodema laevigatum* *Trigonotylus ruficornis*	
				Tingidae (1) *Tingis cardui*	Piesmidae (1) *Piesma maculata*	

				Lygaeidae (2) *Kleidocerys resedae* *Nysius thymi*	Pentatomidae (3) *Dolycoris baccarum* *Eurydema oleracea* *Palonema viridissima*	
Kinnunen et al. (2001)	Southern Finland	not specified	pitfall trapping	Carabidae (15-33) *Bembidion properans* *Bembidion quadrimaculatum* *Calathus erratus* *Clivina fossor* *Harpalus rufipes* *Pterostichus melanarius*		only dominant species and species almost exclusively occurring in potato given
Karley et al. (2003)	Western Great Britain	cv. Wilja	visual examination, sticky traps	Aphidae (5) *Aphis fabae* *Aphis nasturtii* *Aulacorthum solani* *Macrosiphum euphorbiae* *Myzus persicae*	Syrphidae (≥ 1) no species given	only aphids determined below family level
				Coccinellidae (≥ 1) no species given	Chrysopidae (≥ 1) no species given	
Bilewicz-Pawinska (1992)	Poland	cv. Pola, cv. Irys	sweep-netting	Miridae (2) *Campylomma verbasci* *Lygus rugulipennis*	Braconidae (2) *Peristenus digoneutis* *Peristenus stygicus*	additional species found but detailed information on these taxa is lacking
				Cicadellidae (2) *Empoasca solani* *Eupteryx atropunctata*	Dryinidae (1) *Aphelopus empoascae*	
Wasylik (1995)	Poland	not specified	Kempson extraction	Acaroidea (6) *Rhizoglyphus robini* *Schwiebea talpa* *Tyrophagus similis* *Tyrophagus longior* *Tyrophagus putrescentiae* *Tyrophagus mixtus*	Glycyphagidae (1) *Glycyphagus demosticus*	
				Oribatei (12) *Brachychochthonius immaculatus* *Hypochtchonius luteus* *Liochthonius propinquus* *Liochthonius strenzkei* *Oppia bicarinata* *Oppia minus* *Oppia obsoleta* *Oppiella nova* *Punctoribates latilobatus* *Scheloribates spec.* *Suctobelbella spec.* *Tectocepheus velatus*	Pygmephoridae (14) *Bakerdania arvorum* *Bakerdania exinqua* *Bakerdania heisseli* *Bakerdania latipilosus* *Bakerdania mirabilis* *Bakerdania quadrata* *Bakerdania tarsalis* *Bakerdania togata* *Brennandania parasilvetris* *Brennandania silvetris* *Pediculatser ignotus* *Petalonium spec.* *Pygmephorus spinosus* *Siteroptes soliter*	

				Tarsonemidae (≥ 1) no species given	Anoetidae (1) *Anoetidae spec.*	
				Ascidae (6) *Arctoseius cetratus* *Arctoseius minutus* *Arctoseius semiscissus* *Arctoseius venustulus* *Cheiroseius mutilus* *Gmasellodes spec*.	Scutacaridae (9) *Diversipes spec.* *Imparipes armatus* *Scutacarus eucomus* *Scutacarus longiusculus* *Scutacarus mihalyii* *Scutacarus montanus* *Scutacarus plumosus* *Scutacarus quadrangularis* *Scutacarus suborbiculatus*	
				Eupodidae (≥ 1) no species given	Stigmaeidae (≥ 1) no species given	
				Nanorchestidae (≥ 1) no species given	Tetranychidae (≥ 1) no species given	
				Alicorhagiidae (≥ 1) no species given	Rhagidiidae (≥ 1) no species given	
				Bdellidae (≥ 1) no species given	Tydeidae (≥ 1) no species given	
				Trombidiidae (≥ 1) no species given	Eviphididae (2) *Eviphis ostrinus* *Alliphis siculus*	
				Podocinidae (1) *Lasioseius fimetorum*	Pachylaelaptidae (1) *Pachylaelaps spec.*	
				Halolaelapidae (1) *Halolaelaps spec.*	Laelaptidae (2) *Hypoaspis aculeifer* *Hypoaspis angusta*	
				Ameroseidae (1) *Ameroseius spec.*	Veigaiaidae (2) *Veigaia decurtata* *Veigaia nemorennsis*	
				Rhodacaridae (8) *Dendrolaelaps fovelatus* *Dendrolaelaps stammeri* *Digamasellus punctum* *Minirhodacarellus spec.* *Rhodacarellus silesiacus* *Rhodacarus calcarulatus* *Rhodacarus haarloevi* *Rhodacarus mandibularis*	Parasitidae (6) *Parasitus coleoptratorum* *Pergamasus crassipes* *Pergamasus digitulus* *Pergamasus misellus* *Pergamasus oxygynelloides* *Pergamasus septentrionalis*	
				Phytoseiidae (1) *Amblyseius spec.*	Macrochelidae (2) *Geholaspis mandibularis* *Macrocheles spec*.	

9 Appendix 2: Studies on arthropods in potato fields from outside Europe

Author	Country	Type of potato	Sampling method	Family (No. of species)		Comments
Ashouri (2004)	Canada	cv. Superior, cv. Kennebec, transgenic potato	visual inspection	Aphidae (2)		
Berlandier (1997)	Southwestern Australia	not specified	sticky traps, water traps, leaf counts	Aphidae (4)		
Binns et al. (1992)	Canada	cv. Superior cv. Kennebec	visual inspection	Chrysomelidae (1)		
Koss et al. (2005)	Northwestern United States	conventional potato, organic potato	D-vac suction sampling, pitfall trapping, visual inspection	Nabidae (≥ 1) Miridae (≥ 1) Lycosidae (≥ 1) Thomisidae (≥ 1) Salticidae (≥ 1) Tetragnathidae (≥ 1) Gnaphosidae (≥ 1) Anthicidae (≥ 1) Carabidae (≥ 1) Cantharidae (≥ 1)	Ciccindelidae (≥ 1) Lycidae (≥ 1) Coccinellidae (≥ 1) Staphylinidae (≥ 1) Chrysopidae (≥ 1) Hemerobiidae (≥ 1) Mantidae (≥ 1) Syrphidae (≥ 1) Dolichopodidae (≥ 1) Anthocoridae (≥ 1) Reduviidae (≥ 1)	no determination below family level
Radcliffe (1982)	United States			Aphidae (12) Cicadellidae (4) Chrysomelidae (2) Gelechiidae (4)	Elateridae (≥ 6) Noctuidae (≥ 1) Scarabaeidae (≥ 1)	review article on potato pests

Hilbeck & Kennedy (1996)	Eastern United States	cv. Atlantic	visual inspection	Chrysomelidae (1) Crambidae (1) Carabidae (3) Coccinellidae (2) Melyridae (1)	Pentatomidae (3) Lygaeidae (1) Mabidae (1) Chrysopidae (1) Vespidae (1)	
Boiteau (1986)	Canada	cv. Russet Burbank	pitfall trapping	Carabidae (≥ 1) Staphylinidae (≥ 1) Arachnida (≥ 1) Aphidae (3)		separation mainly restricte d to higher taxonomic level
Chang & Snyder (2004)	United States	conventional potato, organic potato	D-vac suction sampling	Nabidae (≥ 1) Lygaeidae (≥ 1) Miridae (≥ 1) Anthocoridae (≥ 1) Thomisidae (≥ 1) Carabidae (≥ 1)	Coccinellidae (≥ 1) Staphylinidae (≥ 1) Reduviidae (≥ 1) Chrysopidae (≥ 1) Hemerobiidae (≥ 1)	no determination below family level
Heimpel & Hough-Goldstein (1992)	Eastern United States	cv. Superior	visual inspection, beating, pitfall trapping	Carabidae (2) Coccinellidae (3) Chrysopidae (1) Staphylinidae (≥ 1) Pentatomidae (2) Lycosidae (1) Phalangiidae (1)		
Obrycki et al. (1983)	Eastern United States	cv. Katahdin, *S. tuberosum x S. berthaultii, S. berthaultii*	visual inspection	Coccinellidae (≥ 3) Aphidiidae (≥ 2)		

Hough-Goldstein et al. (1993)	Mainly United States and Mexico			Podapolipidae (1) Pyemotidae (1) Phalangiidae (1) Thomisidae (2) Chrysopidae (2) Pentatomidae (≥ 9) Nabidae (≥ 1) Reduviidae (≥ 1) Miridae (2) Tachinidae (4)	Coccinellidae (6) Cicindelidae (1) Staphylinidae (1) Carabidae (5) Eulophidae (1) Chalcididae (1) Mymaridae (1) Vespidae (1) Formicidae (3)	review article without own investigations
Boiteau (1983)	Canada	not specified	sweepnet, ground cloths, yellow waterpans, pitfall trapping	Calliphoridae (≥ 1) Sarcophagidae (≥ 1) Scatophagidae (≥ 1) Muscidae (≥ 1) Dolichopodidae (≥ 1) Tachinidae (≥ 1) Syrphidae (27) Anthocoridae (≥ 1) Nabidae (≥ 1) Nygaeidae (≥ 1) Saldidae (≥ 1) Pentatomidae (≥ 1) Miridae (≥ 1) Aphididae (4)	Cicadellidae (≥ 1) Cercopidae (≥ 1) Membracidae (≥ 1) Aleyrodidae (≥ 1) Fulgoroidae (≥ 1) Psyllidae (≥ 1) Carabidae (≥ 1) Chrysomilidae (≥ 1) Coccinellidae (16) Curculionidae (14) Elateridae (≥ 1) Staphylinidae (16) Aphidiidae (≥ 1)	> 560 taxa in total; exact numbers of species provided only for certain groups
Drummond et al. (1990)	Northeastern United States	cv. Caribé, cv. Russet Burbank	visual counts, pitfall trapping	Chrysomelidae (1) Phalangidae (1)		
Groden et al. (1990)	Northeastern United States	cv. Caribé	visual counts	Chrysomelidae (1) Coccinellidae (1)		
Boiteau et al. (2000)	Canada	not specified	sampling tower	Carabidae (57) Elateridae (46)		recording of flying insects; also other crops than potato in surroundings

Duan et al. (2004)	Northwestern United States	cv. Russet Burbank, transgenic potato	pitfall trapping	Entomobryidae (≥ 1) Hypogastruridae (≥ 1) Aranae (≥ 1) Formicidae (≥ 1) Carabidae (≥ 1) Staphylinidae (≥ 1)	Anthicidae (≥ 1) Cetoniidae (≥ 1) Curculionidae (≥ 1) Scarabaeidae (≥ 1) Lathridiidae (≥ 1)	no determination below family level
Kabaluk et al. (2006)	Canada	not specified	visual counts, sweep-net sampling	Aphidae (1) Coccinellidae (≥ 2) Hymenoptera (≥ 1)		
Coll et al. (2000)	Israel	cv. Kara, cv. Mondial, cv. Desiree	pheromone traps, visual inspection	Gelechiidae (1) Coccinellidae (1) Chrysopidae (1) Anthocoridae (1) Formicidae (4)		
Snyder & Clevenger (2004)	Eastern United States	not specified	hand sampling	Coccinellidae (4)		mainly laboratory experiment

10 Appendix 3: Abbreviations of countries

According to ISO 3166

AT: Austria
B: Belgium
CH: Switzerland
D: Germany
EE: Estonia
F: France
FI: Finland
GB: Great Britain
HR: Croatia
IE: Ireland
LV: Latvia
NL: Netherlands
NO: Norway
PL: Poland