BioControl (2010) 55:199–218
DOI 10.1007/s10526-009-9234-9

FORUM PAPER

Do new Access and Benefit Sharing procedures under the Convention on Biological Diversity threaten the future of biological control?

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Received: 25 August 2009 / Accepted: 28 September 2009 / Published online: 1 December 2009

Abstract Under the Convention on Biological Diversity (CBD) countries have sovereign rights over their genetic resources. Agreements governing the access to these resources and the sharing of the benefits arising from their use need to be established between involved parties [i.e. Access and Benefit Sharing (ABS)]. This also applies to species collected for potential use in biological control. Recent applications of CBD principles have already made it difficult or impossible to collect and export natural enemies for biological control research in several countries. If such an approach is widely applied it

Handling Editor: Eric Wajnberg.

Electronic supplementary material The online version of this article (doi:10.1007/s10526-009-9234-9) contains supplementary material, which is available to authorized users.

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would impede this very successful and environmentally safe pest management method based on the use of biological diversity. The CBD is required to agree a comprehensive Access and Benefit Sharing process in 2010, in preparation for which the IOBC (International Organization for Biological Control of Noxious Animals and Plants) Global Commission on Biological Control and Access and Benefit Sharing has prepared this position paper. Here, we first describe the practice of biological control in relation to the principles of ABS, illustrated extensively by case studies and successes obtained with biological control. Next, we emphasise the very limited monetary benefits generated in biological control when compared to other fields of ABS such as the collection of germplasm for development of human drugs, chemical pesticides or crop cultivars. Subsequently, we inform the biological control community of good ABS practice and challenges, and we hope to make clear to the community involved in ABS under the CBD the special situation with regard to biological control. Finally, based on the non-commercial academic research model, we make recommendations which would facilitate the practice of collection and exchange of biological control agents, propose a workable framework to assist policy makers and biological control practitioners, and urge biological control leaders in each country to get involved in the discussions with their national ABS contact point to take their needs into consideration.

Keywords Biological control · Access and Benefit Sharing · Convention on Biological Diversity · History · Monetary · Non-monetary · Genetic resources, biological control agent

Abbreviations

ABC	Augmentative biological control
ABS	Access and Benefit Sharing
BC	Biological control
BCA	Biological control agent
CBC	Classical biological control
CBD	Convention on Biological Diversity
COP	Conference of Parties
IOBC	International Organization for Biological Control of Noxious Animals and Plants

Introduction

Biological control (BC)—the use of an organism to reduce the population density of another organism—is one of the most environmentally safe and economically profitable pest management methods (Cameron et al. 1989; Clausen 1978; Cock 1985; Mason and Huber 2002; Neuenschwander et al. 2003; Waterhouse and Sands 2001). BC can contribute to solve or help to manage indigenous and alien pest problems in diverse natural and managed ecosystems. In BC, parasitoids, predators, pathogens, herbivores and antagonists are used to reduce populations of pests, diseases and weeds. We examine BC as practised over the last 120 years during which at least 165 pest and weed species have been brought under permanent or temporary control. During this period, more than 7,000 introductions of biological control agents (BCAs) involving almost 2,700 species have been made, and in addition 170 species are produced and sold globally for periodical release to control more than 100 pest species (see "On-going practice in biological control in relation to Access and Benefit Sharing" of this paper).

Alien species are being introduced accidentally or deliberately around the world at an increasing rate, driven by factors such as increasing trade, travel and tourism (Wittenberg and Cock 2001). A proportion of these become established and a proportion of those established become pests or invasive in natural habitats. In addition, as most of the world's crop plants are alien species in much of the area where they are grown, there remains great potential for pests from the crops' areas of origin to be introduced into new areas. Furthermore, the spread around the world of new crops such as those grown for agrifuel, will create new opportunities for pest introductions.

In contrast, deliberate introductions and releases of exotic BCAs have resulted in remarkably few problems (Lynch et al. 2001), although there are some exceptions (Howarth 1991; Louda et al. 2003). Nevertheless, risk analysis for non-target species is now recommended for BC programmes (Bigler et al. 2006; IPPC 2005; van Lenteren et al. 2006). Initially, it was thought that this would impede new BC programmes, but results published by Kairo et al. (2003) indicate that, although some delay in application may occur, the annual number of new natural enemies becoming available for use has not decreased. However, a new and potentially serious threat to the use of BC has recently become apparent. Under the Convention on Biological Diversity (CBD), countries have sovereign rights over the genetic resources within their boundaries and that agreements governing access to genetic resources and sharing of benefits arising from their use should be established between the parties involved. This is known as Access and Benefit Sharing (ABS). ABS applies to all BCAs taken from one country to another. BC practitioners will need to comply with whatever ABS regime is agreed by the tenth meeting of the Conference of the Parties to the CBD (COP10) in 2010. Recent applications of CBD principles have already created barriers to collection and export of natural enemies for BC research (Case Studies 1–3; for all case studies see Annex 1—Electronic supplementary material) in several countries. If this approach is widely applied it will seriously compromise this very successful and environmentally safe pest management method.

Unlike some other uses of genetic resources (e.g. in medicine), traditional knowledge held by individuals and communities of indigenous people (a strongly argued principle under the CBD) is not relevant to finding and identifying potentially useful natural enemies, and there is no case known where such knowledge would have been needed. This should not be confused with local scientific knowledge about habitats, fauna and flora, which clearly can assist in finding appropriate locations for surveys and collections. Bioprospecting is the search for plant and animal species from which medicinal drugs and other commercially valuable compounds can be obtained, whereas biopiracy is bioprospecting without permission of the country that owns the genetic resources and which exploits plant and animal species by claiming patents to restrict their general use. The search for BCAs should not be confused with bioprospecting or biopiracy, which is most often concerned with products that can be protected with intellectual property rights in order to generate monetary profits for companies (e.g. pharmaceuticals and seeds). Equally BCAs are not modified genetically and so should not be considered together with genetically modified organisms as they do not come under the Cartagena Protocol of the CBD.

This paper is partly based on a report prepared for the Food and Agriculture Organization of the United Nations (FAO) by the authors, in their capacity as members of the IOBC Global Commission on ABS (Cock et al. 2009; IOBC 2008). The report specifically addressed the use of invertebrates in BC, and while this bias has been maintained here, the principles presented are directly applicable to the use of pathogens in BC. The report to FAO was concerned with BC principally in the context of agriculture and forestry, although BC is increasingly commonly used to address pests of natural ecosystems (Wittenberg and Cock 2001; Case Study 4). Furthermore, BC has been used or considered for pest management in other sectors including management of vectors of human and animal diseases, pests of humans and animals, nuisance and disease-transmitting flies breeding in animal dung, alien species in other production systems, e.g. water weeds affecting fisheries, transport, power generation, etc. (Case Study 5), and ecosystem services such as recycling animal dung in pasture. The same principles of ABS apply in all these uses. This report included a series of case studies which are included here as Electronic supplementary material available on the journal website. These are intended to provide real examples of many of the points made and to bring out issues relating to ABS in the practice of ABC and CBC.

In this paper, we aim to:

1. clarify the practice of BC in relation to the principles of ABS, illustrating the benefits for countries providing BCAs,
2. demonstrate the very limited monetary benefits generated in BC when compared to other uses of biodiversity,
3. inform the BC community of good ABS practice and challenges, and
4. inform the ABS/CBD community of the special situation with regard to BC.

Based on this information, we make recommendations which will facilitate the practice of collection and exchange of BCAs, and propose a workable framework to assist policy makers and practitioners of BC.

What is happening under the Convention on Biological Diversity?

Up until now most BC practitioners are still unaware of the implications of ABS under the CBD. The three objectives of the Convention on Biological Diversity (1993) are:

- The conservation of biological diversity;
- The sustainable use of its components;
- The fair and equitable sharing of the benefits arising out of the utilisation of genetic resources.

The CBD is an international framework convention, and its provisions are binding on its contracting parties. However, it is unable to prescribe how decisions are to be implemented by the parties since different countries have different legal structures. Nonetheless, it is now internationally recognised that countries have sovereign rights over the biological resources within their boundaries (generally perceived as ownership), and so agreements governing the access to these resources and the sharing of the benefits arising from them should be established and agreed between the parties involved. To facilitate the implementation of this principle, in 2002 the Conference of Parties (COP) to the CBD adopted the 'Bonn Guidelines on Access to Genetic Resources and Fair and Equitable Sharing of Benefits Arising out of their Utilization' (SCBD 2002, Decision VI/24). Genetic resources are defined by the CBD as genetic material, i.e. material containing functional units of heredity that is of actual or potential value (CBD Art. 2). The value of the genetic resources need not be commercial (i.e. monetary), but may be scientific or academic in nature. As the CBD definition also includes the potential value of such resources, in effect all genetic material falls under the provisions of the ABS system. The CBD is required to prepare a global ABS regime for consideration and agreement at COP10 in 2010, and this will include all biological control agents.

The term 'access' has not yet been officially defined, so its meaning depends on its interpretation by the providing countries. This may involve various activities, for example, entering a location where genetic resources are found, surveying activities, and acquisition of genetic resources for study for scientific or commercial purposes. Prior informed consent is now prescribed by the CBD for the utilisation and research of (=access to) genetic resources. Each participating country has assigned a competent national authority, and these agencies must be informed of any planned research as part of the application process. Prior informed consent from the competent agency is a necessary prerequisite for access to biological resources. Mutually agreed terms are usually laid down in a contract established between the users and providers of genetic resources. These terms define the conditions governing access to genetic resources and grant permission for their use and incorporate an understanding regarding the sharing of the benefits arising from the utilisation of the genetic resources. These agreements are in addition to each country's existing BCA export (and import) regulatory processes already in place for phytosanitary measures, CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora; http://www.cites.org/), etc.

What are the implications of the Convention on Biological Diversity for biological control?

The practice of BC will need to comply with whatever ABS regime is agreed by COP10 in 2010. If the measures described above are applied, prior informed consent and mutually agreed terms potentially with monetary benefit-sharing mechanisms would need to be developed for every BC initiative with every potential source country where research is planned. BC practitioners need to understand these possible implications, which raise concerns paralleled by the academic non-commercial research community (Jinnah and Jungcurt 2009).

Biological control agents are living organisms of largely unknown value unless they have been previously used in BC. They need to be collected from the field, studied, cultured (usually) and carefully transported to the receiving country. Access and permission to export currently depend on national regulations, the legislation for which may or may not address ABS issues. We have outlined the processes by which access to BCAs are regulated and how benefit sharing is handled for a variety of countries and regions (see Annex 2, Electronic supplementary material) and the perceptions of some of the major users (see Annex 3, Electronic supplementary material). From analysis of this information we conclude that some countries, such as Brazil and India (Case Study 2), have legislated for ABS aspects of BC research, while others are considering doing so (the CBD webpage on ABS measures, http://www.cbd.int/abs/measures.shtml provides information for each country). Where such legislation is in place, BC researchers have found that it has posed an administrative barrier to research and export of BCAs, partly because no one understands the new process. As a result these countries are only approached as potential sources of BCAs when no administratively simpler source country can be identified. Nevertheless, BCAs have been exported successfully from Brazil under their ABS legislation, including phytoseiid predators, such as *Amblyseius aripo* (DeLeon), the most important BCA credited with bringing the chronically damaging cassava green mite (*Mononychellus tanajoa* Bondar) under control in Africa (Yaninek 2003). Many countries have not yet considered the needs of BC in their legislation and planning for ABS to date. The BC community recognises that some countries that were restrictive with regard to access to BCAs are now introducing clearer mechanisms to implement regulations. However, at the same time others are passing new legislation which is not necessarily designed with BC in mind, and they will become restrictive in the short to medium term (Case Study 3).

Although many countries have not yet considered the needs of BC in their legislation, on the other hand, much of the BC community has also been unaware of the potential of ABS to stop its activities. Some region-specific responses to the concern that legislation might hinder the practice of BC are summarised in Appendix 2 (Electronic supplementary material).

Over the last 20 years, the introduction of BCAs has increasingly followed international or national legislation. ISPM3 (International Standards for Phytosanitary Measures No. 3) of the International Plant Protection Convention (IPPC 2005) sets out the responsibilities of the different players, but does not address the issue of ABS. Since the earliest days of BC, there has been a community of practice based on free multilateral exchange of BCAs (most Case Studies, but especially 6), rather than bilateral exchange or defined benefit sharing agreements. Indeed, it has usually made good practical sense to collaborate with a research organisation in a source country, especially given recent requirements for more detailed risk and environmental impact assessment studies. Despite allowing access to BCAs for use in another country imposing no risk of liability to the source country, there is a general trend for access to potential BCAs to become increasingly restrictive because of phytosanitary legislation not designed for BC, and ABS issues. In these circumstances the implementation of BC is becoming increasingly difficult and challenging for both international researchers and their national collaborators (Case Studies 1–3). There is a risk that ABS legislation will add another layer of regulations which is likely to hinder the process. As will be presented in the next section, countries that are providers of BCAs are almost always users of BC. Therefore, it is in their national self-interest to maintain free multilateral exchange of BCAs.

On-going practice in biological control in relation to Access and Benefit Sharing

In order to place BC in context, it was considered important to provide information on the extent of use of BC, i.e. what BCAs have been used, where, and how successfully. We have, therefore, prepared comprehensive listings of the insect BCAs used for both classical and augmentative biological control based on existing databases, recent literature and international contacts.

Classical biological control

Classical biological control (CBC) is the introduction of a BCA, usually from a pest's area of origin, to control the pest in an area where it has invaded. Once introduced, the BCA will become established, reproduce and spread, and have a self-sustaining effect on the target pest. For insects used as BCAs against insects for CBC, CABI (http://www.cabi.org/) has maintained the BIOCAT database for many years, which includes basic information about all insects introduced to control other insects (Greathead and Greathead 1992). For this review, we used the database as it stood up to 2006, which includes 5,558 records, and the great majority of all insect introductions. There was no database for mites as BCAs, apart from regional reviews of BC (e.g. Cameron et al. 1989; Clausen 1978; Cock 1985; Mason and Huber 2002; Neuenschwander et al. 2003; Waterhouse and Sands 2001). These sources and other literature searched yielded 168 introductions. Information on nematodes used as BCAs of insects was taken from Hajek et al.'s (2005) catalogue of pathogens and nematodes for CBC of insects and mites, and comprised 29 introductions. A list of 90 introductions of snails and planarians used as BCAs for snails was compiled from some of the sources listed under mites above, and from a more general literature survey. Arthropods used as BCAs for control of weeds were taken from Julien and Griffiths (1998) World Catalogue of Weed Biological Control Agents, which covers the period up to the end of 1996, and includes 1,160 releases (including pathogens). This was supplemented by a literature search and personal contacts focussed on Australia, Canada, New Zealand, South Africa and USA—the five countries which consistently invested most in weed BC—which produced a further 131 new releases. In this way, we were able to compile a reasonably complete dataset of all CBC introductions using invertebrates. Based on this compilation, 7,094 introductions of BCAs involving about 2,677 BCA species have been made. Of these 1,070 have been used more than once, and the remaining 1,607 only once, although this number is probably an overestimate owing to uncertainties of taxonomy. The most widely used BCAs have been introduced more than 50 times (Case Study 7; Table 1). An example of the information in the BIOCAT database concerning 43 introductions of *Rodolia cardinalis* to control *Icerya purchasi* is presented in Annex 4 (Electronic supplementary material).

Of the 7,094 introductions, 222 were within different parts of the source country, of which 171 were from mainland USA to Hawaii. The remaining 6,872 introductions were between different countries, and involved BCAs from 119 countries introduced into 146 countries (Table 2). These are independent countries only, so that more than 1,000 introductions in overseas non-independent territories associated with the former colonial powers are treated as part of that country (France, UK, USA, etc.).

Of these 7,094 introductions, 449 involved material from more than one country. Treating each of these as a separate introduction, and eliminating all records where the source is ambiguous, leaves 6,331 introductions where a source country is clearly identified (Table 3). However, since most of the data are based on published sources, this total also includes some countries which were secondary sources of BCAs, i.e. the BCAs were themselves introduced in those countries.

The data on introductions are not yet in a form that enables us to generate statistics on establishment and impact. However, there are clear indications available from earlier surveys. Greathead and Greathead (1992) analysed an earlier version of the BIOCAT database of insect BC using insects with 4,769 records. Of these, 1,445 (30%) were known to have resulted in establishment and 517 (11%) achieved substantial control of the target pest. These rates are probably conservative for CBC as a whole, since the rates in weed BC tend to be higher, and the establishment and impact rates have improved in recent decades, following on from the introduction of more careful study and evaluation of potential BCAs. Historically, one of 10–20 released natural enemy species has contributed to the reduction of the target pest and this makes clear that not all collected, evaluated and released species produce benefits for the receiving country. However, the success rate has been increasing in recent decades, as introductions are based on more sophisticated evaluation of the BCAs, the associated risks and potential impact.

The implementation of CBC in poorer countries depends almost entirely on donor assistance, often linked to the availability of BCAs as spin-offs from research in wealthier countries. BC research targeted at pests primarily of concern to poorer countries is rare, and in the case of weed BC, the long-term nature of the research and the need to carry out much survey and evaluation research in other countries can make this superficially unattractive to donors (Cock et al. 2000). Nevertheless, targeted CBC research has been shown to have enormous potential benefits to these countries (Case Study 8). Throughout the history of BC, BCAs that are effective in one country have been forwarded to other countries affected by the same pest problem (e.g. Case Studies 7, 9). In the past this was sometimes done rather casually (Case Study 10), without due consideration of the possible risks, but following the introduction of the International Standard for Phytosanitary Measures (ISPM) No. 3 (IPPC 1996, 2005), this practice has been reduced (Kairo et al. 2003). Access to such tested BCAs is one way that developing countries have benefited from research and implementation carried out by wealthier countries. This is particularly true of the work of wealthier countries in subtropical and tropical regions, where work by Australia, South Africa, and the USA has been of direct benefit to developing

Table 1 The most frequently used biological control agents (BCAs) for classical biological control, ranked by number of countries where they have been released, based on data extracted from the database of introductions compiled for this work

Biological control agent	Classification (insects except as stated otherwise)	Origin	Target(s)	Number of countries where BCA was released
Cryptolaemus montrouzieri	Coccinellidae	Australia	Mealybugs	58
Rodolia cardinalis	Coccinellidae	Australia	*Icerya purchasi*	56
Diachasmimorpha longicaudata	Braconidae	SE Asia	Fruit flies	49
Teleonemia scrupulosa	Tingidae	Neotropical	Lantana weed, *Lantana camara*	39
Cotesia flavipes	Braconidae	South Asia	Sugarcane stem borers (Crambidae)	38
Aphelinus mali	Aphelinidae	North America	Woolly apple aphid, *Eriosoma lanigera*	37
Euglandina rosea	Mollusca, Gastropoda, Spiraxidae	USA	Other snails	35
Lixophaga diatraeae	Tachinidae	Caribbean	Sugarcane stem borers (Crambidae)	35
Neochetina eichhorniae	Curculionidae	Neotropical	Water hyacinth, *Eichhornia crassipes*	35
Uroplata girardi	Chrysomelidae	Neotropical	Lantana weed, *Lantana camara*	31
Cotesia plutellae	Braconidae	Europe	Diamondback moth, *Plutella xylostella*	29
Encarsia perniciosi	Aphelinidae	East Asia	San José scale, *Quadraspidiotus perniciosus*	29
Neochetina bruchi	Curculionidae	Neotropical	Water hyacinth, *Eichhornia crassipes*	28
Lydella minense	Tachinidae	Brazil	Sugarcane stem borers, mainly *Diatraea* spp.	27
Paratheresia claripalpis	Tachinidae	Neotropical	Sugarcane stem borers, mainly *Diatraea* spp.	26
Rhinocyllus conicus	Curculionidae	Europe	Thistles, especially nodding thistle, *Carduus nutans* group	26
Cactoblastis cactorum	Pyralidae	Argentina	Prickly pear cacti, *Opuntia* spp.	24
Trissolcus basalis	Scelionidae	Widespread	Green stink bug, *Nezara viridula*	24
Ageniaspis citricola	Encyrtidae	SE Asia	Citrus leaf miner, *Phyllocnistis citrella*	23
Aphytis lingnanensis	Aphelinidae	SE Asia	Red scale, *Aonidiella aurantii*	23
Cryptognatha nodiceps	Coccinellidae	Neotropical	Armoured scales, Diaspidae	23
Apoanagyrus lopezi	Encyrtidae	Brazil, Paraguay, Bolivia	Cassava mealybug, *Phenacoccus manihoti*	22

Table 2 The numbers of classical biological control (CBC) introductions made in different countries, based on data extracted from the database of introductions compiled for this work

Number of releases per country	Number of countries	Total number of releases in these countries	% Of total releases
>100	12[a]	4,231	61.6
50–100	14[b]	997	14.5
10–49	55	1,399	20.4
1–9	65	245	3.6
Total	146	6,872	100

[a] In order by the number of releases made: USA, Australia, Canada, New Zealand, South Africa, UK (almost entirely overseas territories), Fiji, Mauritius, India, France (mostly overseas territories), Israel, Guam

[b] In order by the number of releases made: Russia, Italy, Barbados, Chile, Trinidad and Tobago, Ghana, Kenya, Philippines, Mexico, St Kitts and Nevis, Papua New Guinea, Greece, Peru, Bahamas

Table 3 The numbers of biological control agent (BCA) species obtained from different countries for classical biological control based on data extracted from the database of introductions compiled for this work

Number of BCAs obtained from country	Number of countries	Total number of BCA introductions from these countries	% Of total releases
>100	16[a]	4,482	70.8
50–100	9[b]	646	10.2
10–49	40	1,032	16.3
1–9	54	171	2.7
Total	119	6,331	100

Only those records where the source is clear are included

[a] In order by the number of times they were the source country for an introduction: USA, India, Australia, Trinidad and Tobago, Mexico, France, Brazil, China, South Africa, Japan, UK, Argentina, Pakistan, Indonesia, Italy, Austria

[b] In order by the number of times they were the source country for an introduction: Philippines, Colombia, Germany, Switzerland, Canada, Kenya, Malaysia, Papua New Guinea, 'Taiwan'

countries in these regions (Case Studies 7, 11). Since BCAs such as these would normally have been re-collected in the receiving country rather than the original source country, the genetic resource ownership is not totally clear (e.g. Case Study 12).

Augmentative biological control

Augmentative biological control (ABC) involves the production and release of indigenous or exotic BCAs into specific crop situations, where they cause mortality of the target pest, but are not expected to persist from one cropping cycle to the next. Where they are exotic, they should under best practice be evaluated before use in a similar way to BCAs for CBC, which is now common practice in several countries (van Lenteren et al. 2006).

In ABC, there are two main groups of producers: commercial and centralised. The former are independent companies who produce and sell BCAs to users operating mainly in developed countries, particularly in Europe and North America. New companies and franchised companies are increasingly common globally, particularly supporting cash crop production in middle-income countries. The centralised production units are government or grower-industry owned and produce natural enemies for a particular niche, normally large-scale agriculture or forestry, which are either provided free or sold to users (van Lenteren 2000; van Lenteren and Bueno 2003; Parra et al. 2002; Case Study 13).

A database was compiled for ABC in Europe building on van Lenteren (2003a, b) and information provided by the ABC industry. As 75% of the sales of

Table 4 The most important biological control agents (BCAs) used in augmentative biological control (ABC) ranked by the number of countries in which each has been used (updated from van Lenteren 2003a, b)

Biological control agent	Family (insects except as stated otherwise)	Source area	Target(s)	No. of countries where used	Year of first use
Amblyseius swirskii	Acari: Phytoseiidae	Israel	Whiteflies, thrips, mites	20	2005
Aphidius colemani	Braconidae	Middle East	Aphids	20	1991
Aphidoletes aphidimyza	Cecidomyiidae	Europe	Aphids	20	1989
Dacnusa sibirica	Braconidae	Europe	Leafminers	20	1981
Diglyphus isaea	Eulophidae	Europe	Leafminers	20	1984
Encarsia formosa	Aphelinidae	Central America	Whiteflies	20	1926
Macrolophus pygmaeus	Miridae	Europe	Whiteflies	20	1994
Neoseiulus cucumeris	Acari: Phytoseiidae	Europe	Thrips	20	1985
Phytoseiulus persimilis	Acari: Phytoseiidae	Chile	Mites	20	1968
Steinernema feltiae	Nematoda: Steinernematidae	Europe	Sciaridae	18	1984
Aphidius ervi	Braconidae	Europe	Aphids	17	1996
Orius laevigatus	Anthocoridae	Europe	Thrips	17	1993
Cryptolaemus montrouzieri	Coccinellidae	Australia	Mealybugs, scales	16	1989
Galeolaelaps aculeifer	Acari: Laelapidae	Europe	Sciaridae	16	1996
Feltiella acarisuga	Cecidomyiidae	Europe	Mites	15	1990
Leptomastix dactylopii	Encyrtidae	South America	Mealybugs	15	1984
Stratiolaelaps miles	Acari: Laelapidae	Europe	Sciaridae	15	1995
Aphelinus abdominalis	Aphelinidae	Europe	Aphids	14	1992
Heterorhabditis bacteriophora	Nematoda: Heterorhabditidae	Europe	Coleoptera	14	1984
Heterorhabditis megidis	Nematoda: Heterorhabditidae	Europe	Coleoptera	14	1990
Neoseiulus californicus	Phytoseiidae	Central America	Mites, thrips	14	1985
Eretmocerus eremicus	Aphelinidae	North America	Whiteflies	13	1995
Eretmocerus mundus	Aphelinidae	Europe	Whiteflies	13	2001
Episyrphus balteatus	Syrphidae	Europe	Aphids	11	1990
Trichogramma evanescens	Trichogrammatidae	Europe	Lepidoptera	11	1975
Chrysoperla carnea	Chrysopidae	Europe	Whiteflies aphids, etc.	10	1987

augmentative BCAs takes place in Europe, the scenarios as outlined below are representative for this form of BC. In ABC worldwide, more than 170 species of natural enemies are produced and sold (Annex 5—Electronic supplementary material—lists the natural enemies available in Europe, their first year of use, their efficacy and market value), but about 25 of these species make up more than 90% of the market value (Table 4). Currently, it is common practice to first look for indigenous natural enemies when a new, even exotic, pest develops, which is mainly to avoid complicated legislation and registration procedures (Fig. 1). In addition, seven exotic natural enemies that were used in Europe have been replaced by indigenous natural enemies recently. Of the 26 natural enemy species commercially allowed for use in Africa, 25 result from material collected in and initially mass reared on other continents. A similar situation exists in Mexico. In Australia and New Zealand almost equal numbers of indigenous

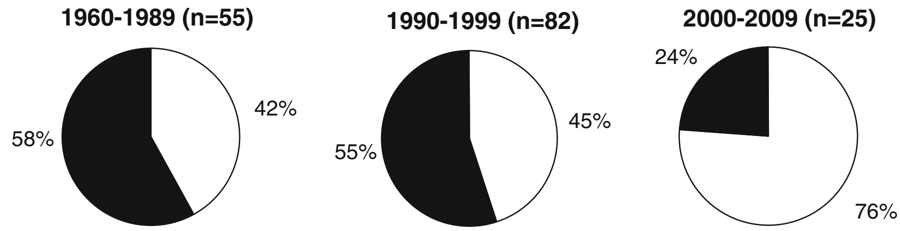

Fig. 1 The changing proportions of first use of exotic (black) and indigenous (white) natural enemies in augmentative biological control (ABC) in Europe over time

and exotic natural enemies are used. The situation is quite different in several South American countries (e.g. Argentina, Brazil) where many of the natural enemies used in ABC are indigenous species.

Research on potential biological control agents and opportunities for joint research

All BC programmes adopt a similar overall approach. We present this in a simplified form below, in order to highlight the points were there are opportunities for shared research and capacity building.

Preparation and planning. This involves a literature survey to find out what is known about the pest and its natural enemies throughout the world. It is necessary to know the area of origin of the pest, and the best place to look for natural enemies, which are not necessarily the same. Sometimes, very little is known about the pest and its natural range (Case Study 14). Preliminary surveys often carried out in different countries are usually followed by more detailed studies focussed on prioritised natural enemies in one or more selected areas. The pest, closely related species and their natural enemies are collected, and usually exported for identification and molecular studies. When several countries are surveyed, identification of each taxonomic group of natural enemies should be done by the same taxonomist, i.e. in the same location. These surveys offer benefit-sharing opportunities for training in survey methods and may yield information of value to the source country, sometimes of unexpectedly high value. For example, exploratory surveys for cassava mealybug, *Phenacoccus manihoti* Matile-Ferrero, in northern South America led to the discovery and taxonomic description of a closely related species, *Phenacoccus herreni* Cox and Williams (1981) in Colombia, the Guyanas and North-east Brazil (Case Study 14). A few years later, when *P. herreni* was devastating cassava production in Brazil, this earlier work greatly facilitated the implementation of a successful CBC programme against *P. herreni* in Brazil (Case Study 8).

There is an important difference between the approach of CBC and ABC: the first search for BCAs in ABC is usually made in the region invaded by the pest to identify indigenous natural enemies that may be suitable for control. This often involves putting pest-infested plants in 'natural areas' and monitoring pest mortality factors. This approach was, for example, used very successfully to find parasitoids for exotic leaf miners in Europe (Case Study 15). Only if there are no suitable indigenous natural enemies, will the search extend to exotic natural enemies in the pest's area of origin.

Detailed studies. These assess the potential of natural enemies and focus on identification, biology, rearing methods, host specificity, impact, potential negative effects, etc. Some studies must be carried out in the source country, e.g. surveying for field incidence, surveying related species to assess host specificity, open field testing to assess specificity and impact. Taxonomic studies may need to be carried out by a specialist at one of the world's museums. During this phase, living cultures of the invertebrate natural enemy would normally need to be established outside the source country for at least some of the detailed studies. This stage provides considerable scope for collaboration, shared research and capacity building. Given that at least 2,500 species of BCAs have been introduced over the last 120 years. This represents a very large amount of research and knowledge relating to the useful biological diversity of the source countries.

Approval and releases. The preliminary studies carry no specific expectation that anything collected and exported will be developed as a BCA, whereas further detailed studies should establish which, if any, natural enemies are suitable for use as BCAs. A dossier based on detailed studies is usually required for the receiving country regulatory authorities to evaluate the risks and potential benefits of making an introduction. On the basis of this dossier, permission for introduction may (or may not) be given with stipulated conditions, following established procedures under national regulations or the IPPC (2005). Although the objective of the whole programme has been towards this end throughout, it is only at this stage that it becomes clear whether a release of a BCA from a particular country will go ahead.

In the past, the research up until this point has assumed that the source country will not object to the release of a BCA exported from their country. Given the potential requirements of an ABS regime, this should no longer be taken for granted even though national regulations may not yet address ABS issues. Consequently, early on in the process there needs to be an understanding with the source country about what further permission may be required, if any, before a BCA is released in the receiving country.

While there is relatively little scope for routinely sharing research in the implementation stage with the source country, there may be scope to build some aspects into capacity building activities, which will assist the source country to implement its own BC releases.

Identification of potential BCAs (and target). Taxonomy provides critical underpinning to BC activities, and is relevant at all steps in a BC programme. Because accurate identification is so important, this needs to be done by internationally recognized taxonomists for each group, and usually complemented with molecular studies. Sometimes this can be done in the source country, but often material will need to be exported for identification. There is no single country that has taxonomic competence for all groups of organisms, so international cooperation is essential. If a BCA is released, voucher material should be preserved and distributed to museums in the source country, receiving country and countries to which the BCA is likely to spread.

As demonstrated under Preparation and Planning (above) and Case Study 8, taxonomic studies of BCAs also provide significant benefits to the source country. Descriptions of new species and new records of previously described species improve the understanding of biodiversity. Voucher specimens in national and international museum collections ensures that the biodiversity of the source country is included in major taxonomic reviews that identify the species but also show the relationship (uniqueness) of the fauna to that in other regions.

Emergency responses

The arrival of a new invasive alien species and pest in a country can be traumatic, and many stakeholders including farmers and members of the public could be affected. There is strong public pressure for action to be taken, which is translated into political will. An emergency can be quickly recognised, for which immediate action is demanded, often to alleviate actual hardship amongst the poorest segments of the population. In these cases, there is an argument that an emergency response may be needed before irreversible harm is done. That emergency response will be CBC in some cases. FAO has been responsive to such demands several times in the last 20 years (e.g. Case Study 16). The need for occasional fast-track procedures for access to genetic resources should be anticipated and facilitated.

Conclusions regarding on-going practice of BC

Based on this overview of the use and global exchange of BC genetic resources and implementation of BC research, we conclude:

- BC is widely used in both developing and developed countries, often using the same BCAs;
- All countries can benefit, and most do, but normally on a multilateral rather than bilateral basis;
- Countries providing BCAs are almost always also users of this technology themselves;
- About 5–10% of the classical BCA introductions have had an impact on the target pest, so many releases do not benefit the receiving countries;
- Historically, most use of BC relates to food and agriculture;
- Benefits already accrue to source countries through biodiversity research and capacity building;
- To improve transparency in the exchange of BCAs, mechanisms to establish and allow free access to database information on BCAs including source and receiving countries globally should be supported;

- In the case of a humanitarian or emergency situation, governments should cooperate to fast track action.

Why biological control is difficult to fit into an Access and Benefit Sharing regime

In most cases monetary benefit-sharing is not appropriate for BC. Here we explain the important distinctions that need to be made between who implements BC, who pays for it, who uses it and who benefits from it, and, linked to this, who is responsible for the benefits which might be shared with the source country.

Implementers and users of biological control

In CBC, national institutes normally take a major role in BC implementation. For developing countries, BC programmes are likely to be supported by international agricultural research agencies such as CABI, *icipe* (http://www.icipe.org/) and the CGIAR (Consultative Group on International Agricultural Research) centres, and occasionally universities. Such agencies commonly take a lead in the exploration for, and evaluation of, natural enemies on behalf of a developing country. The relatively high up-front costs of BC control research means that countries with a common problem are increasingly collaborating by sharing research and research costs. For example, much of the work that CABI does on weed BC for North America is jointly funded by Canada and the USA; Australia and New Zealand cooperate on some targets; CABI, South Africa and the USA have collaborated with Brazil to study BCAs of water hyacinth (*Eichhornia crassipes* (Mart.) Solms; Pontederiaceae) in the Upper Amazon, etc. The national agencies use CBC to achieve long-term effective pest management for the benefit of one or more sectors of their country, including agriculture, forestry and fisheries, as well as human and animal health and the environment. In addition to government agencies, national industry groups or producer boards, and local governments within a country, e.g. provincial or state governments might take some responsibility for pest management including BC. Donors and international agricultural research centres may use CBC to meet their shared objectives with developing countries to reduce pesticide use, improve food security, strengthen sectors of the economy or protect the environment.

The main uses of agents produced for ABC are currently in (a) greenhouses, where IPM based on BC of key pests is widely practised in Europe and North America; (b) open field agriculture and forestry in various countries in Latin America, China and elsewhere, usually for cash crops; and (c) domestic residences, public places (including offices, hospitals, shopping malls, botanical gardens, etc.), and research facilities. The latter involves a relatively small market, but uses many more different species of natural enemies. In all these situations, pesticide use is deemed unacceptable because of human health risks or the need for residue-free plants. In most ABC, it is the growers who purchase the BCAs who reap the benefits in terms of effective pest management, with little or no pesticide use.

Sources of biological control agents

As the true origin of a target pest is often difficult to establish, surveys in several countries need to be made. Without simple access to countries within the source region of the pest, exploration for natural enemies is impractical.

At least 117 countries have at some stage provided a BCA to another. Providers are normally the source countries of the target invertebrate or weed pest. Larger countries with a high degree of endemicity (e.g. Australia, Brazil, Madagascar and South Africa) are likely to be more important in this regard than smaller ones, although usually BCAs can be sourced from more than one country. In this case ease of collaboration under an ABS regime could become an important factor in developing collaboration. In Table 5 we show source and receiving countries of CBC on the basis of the World Bank country groups by income (World Bank 2009). While it is clear that high-income countries have implemented CBC more than middle- and low-income countries have, it is also clear that all groups have participated. Equally, high-income countries have been the main source of BCAs, and although low-income countries have contributed more BCAs than they have received, the numbers are not totally disproportionate. Source countries are also user countries in BC.

Table 5 The supply and use of biological control agents (BCAs) in classical biological by country income economy groups (World Bank 2009)

	BCAs obtained				BCAs released			
	Number of countries providing BCAs	Number of different BCA species provided by these countries	% Of total number of BCA species used globally	Average number of BCA species provided/country	Number of countries releasing BCAs	Total number BCA species released in these countries	% Of total number of BCA species released globally	Average number of BCA species released/country
High-income economies	28	3,100	49.0	111	33	4,078	63.7	124
Upper middle-income economies	30	1,310	20.7	44	31	1,355	21.2	44
Lower middle-income economies	31	1,375	21.7	44	37	666	10.4	18
Low-income economies	26	491	7.8	19	37	148	2.3	4
Unclassified	2	55	0.9	28	7	152	2.4	22
Total	117	6,331	100		145	6,399	100	

Oceanic islands, including most Small Island Developing States, suffer disproportionately from invasive alien species, and are seldom the source of invasive alien species themselves (Wittenberg and Cock 2001). Correspondingly, they are very rarely the source of BCAs (except those introduced for BC), but they are major beneficiaries, as partially shown in Tables 2 and 3.

Addition of value to publicly available biological control agents

BC does not involve simply taking a BCA from one country and releasing it in another, it is usually a lengthy and challenging research process (see "Research on potential biological control agents and opportunities for joint research"). In addition to studies on finding a good natural enemy (identification, biological studies on efficacy and host range, impact studies in laboratory and field, development of rearing methods, release strategies and monitoring procedures), issues such as the risk to humans, economic plants and the environment need to be addressed (Bigler et al. 2006; van Lenteren et al. 2006). Evaluating a natural enemy as a potential BCA requires a substantial investment and makes the natural enemy increasingly useful as a BCA. However, this work could also demonstrate that the natural enemy is not suitable for use as a BCA.

Value is further added by publishing the results of BC projects, which are then freely available and may lead to re-use of natural enemies in other countries (Case Studies 7, 9, 11). Finally, BC studies add value and provide direct benefits to the source country in terms of information about biodiversity and ecosystem services, and new knowledge about the natural BC already operating in the source country, needed to develop the best IPM methods in that country.

Benefits and beneficiaries of biological control

It is appropriate to separate the benefits that accrue to the implementing agency or company providing a BCA, from the benefits that accrue to the user, the local community and the country. If a pharmaceutical company discovers a new drug through bioprospecting that provides, for example, a reliable, safe cure for a major global disease, it is clear that they paid for the work, they carried out the research, and they will make profits by patenting the new drug and selling it with a profit margin. Within an ABS approach, the pharmaceutical company will share these monetary gains with the source country based on the agreement made when they did the bioprospecting. Those who are cured of the disease and the economies of the countries where the disease was prevalent will also benefit, but as far as we are aware this is considered a non-monetary benefit, and no one has suggested that the source country expects to directly share these benefits with the individuals and countries that benefit, even though the benefits might be substantial. Below, we address benefits of BC for the user, community and country.

Food security. One of the simplest and most obvious benefits of implementing BC is in terms of reduced crop losses caused by pests, leading to improved food security and improved or restored livelihoods. This is especially the case with CBC of food or forage crop pests. There are some dramatic success stories in BC and Case Studies 8, 9 and 17 give an indication of what has been achieved. All parts of the world have benefited at different times in this way. This is very much the public good domain of BC, as the benefits reach all who grow and benefit from the crop, without requiring intervention. Indeed it has been said that the benefits of CBC are often obtained in spite of the farmers' actions (such as possible continued pesticide use), not because of them. Currently, many farmers switch to BC based pest management, because it is often no longer possible to control their pests with chemical pesticides due to pesticide resistance (Case Study 18).

Food safety and farmers' and workers' health. Another positive aspect of BC is the requirement that farmers stop applying pesticides or use them in an integrated way to protect the natural enemies. This reduction in pesticide use has clear human health benefits and reduced medical costs from exposure to pesticides. Benefits also accrue from reduced pesticide residues in food, as well as potentially reducing the use of foreign exchange to purchase pesticides.

Livelihoods and poverty alleviation. BC can affect livelihoods through job creation. To make ABC products available in developing countries it is necessary to establish mass-production facilities which creates job opportunities and develops skills of workers, as well as the creation or retention of large numbers of jobs in production systems which depend upon ABC.

Environment and conservation benefits. Reduced pesticide use due to BC will also have environmental benefits, for example, in terms of reduced drift from agriculture to adjacent land, reduced run-off and contamination of above- and below-ground water sources, and reduced impact on crop biodiversity. The environment sector increasingly needs to deal with invasive alien species that affect biodiversity, and BC is one of the few options available to land managers (Case Studies 19 and 20).

Commercial benefits from improved production. Large agricultural economies will show much greater commercial benefits from BC compared with smaller economies. Thus, the biggest benefits tend to relate to widespread weeds and insect pests of important crops in countries such as the USA, Canada and Australia. The benefits in developing countries would need to be evaluated in the local context—for example, although the economic return of the successful BC programme against cassava mealybug in Africa (Neuenschwander 2003) is substantial, it is the impact in terms of food security for this staple food crop throughout much of tropical Africa which sets the value of this programme in its true perspective.

For all the weed BC programmes which Australia has undertaken over many years, Page and Lacey (2006) analysed the costs and benefits for both the successful and unsuccessful programmes and estimated an annual benefit:cost ratio of 23:1. These authors further state that "based on this ratio and where an annual investment in weed biocontrol of approximately [Aus]$ 4.3 million is continued into the future, it is expected that weed biocontrol projects may provide, on average, an annual net benefit of [Aus]$ 95.3 million of which [Aus]$ 71.8 million is expected to flow to the agriculture sector".

The financial benefits of CBC of insect pests are less well documented, with only a few notable exceptions (Greathead 1995). For example, the Alfalfa weevil, *Hypera postica* (Gyllenhal) (Coleoptera: Curculionidae), was controlled in the USA at a cost of US$ 1 million, producing savings of US$ 77 million, discounted over 32 years, and Rhodes grass scale, *Antonina graminis* (Maskell) (Hemiptera: Pseudococcidae), was controlled in Texas for just US$ 200,000 giving savings of $ 194 million discounted over five years.

There are many more examples of successful CBC and ABC programmes, which have generated benefits in agriculture, forestry and the environment (Case Studies 7, 8, 9, 10, 12, 13, 15, 16, 17, 18, 19, 21, 22 and 23 all illustrate examples), but the benefits are seldom quantified. Whole industries would have closed down locally without the support of BC (Case Studies 7, 8, 16, 17, 18). Species would have become extinct, and habitats irreversibly changed (Case Study 19).

Control of genetic resources used in biological control

Many genetic resources that generate monetary benefits involve a product, e.g. a drug, which can be protected with patents, sold and licensed, generating profits and royalties for the specific company. This is not the case with BCAs, which cannot be patented as they are living organisms. Once released and established in a receiving country, a BCA is in the public domain, and anyone can collect it from the field and potentially make money from it. The ABC company that develops a new BCA invests in its development and would have responsibilities for benefit sharing if it is an introduced BCA, whereas another company that collected and exploited this BCA in the receiving country would have no such obligations.

BCAs will spread on their own once established in a country, and spread to the limits of suitable climate and food availability, not respecting national boundaries. So BCAs can easily spread from one country to another without human assistance (e.g. Case Study 24). This is the main reason why importing countries are encouraged to consult with their neighbouring countries when considering the release of new BCAs for CBC. Countries to which BCAs spread may thus obtain the benefits of a BCA without being involved in research or implementation, or having any direct responsibility for benefit sharing.

The scope for making profits with biological control

In the case of CBC, a national or international research institute may carry out the research, with funding from a government or development agency. The research institute may find, study and release a

BCA, but once released, it ceases to be under their control, breeds, disperses and all being well brings the target pest under control. The research institute will not be paid any more than the costs of the research and cannot generate a profit from its action. Patenting of a BCA is impossible and not considered anyway, since the research institute will put all that it has learnt into the public domain, and often encourage other countries to take advantage of this new BCA. Farmers and consumers benefit, as may the local economy, but these benefits do not return to the research institute or development agency in a monetary form, nor does a funding government receive a direct return, although it may need to spend less on health treatment, and receive more in taxes from an improved economy. Thus, those implementing CBC are not in a position to share monetary benefits as they receive none. Clearly there can be substantial benefits to individuals and society from applying CBC, but these are not in a form that can be easily measured and collected and hence are very difficult to share with the source country.

An ABC company, after finding a promising BCA, will study, mass produce and sell it. The ABC company has very little protection for its investment, except to keep secret its production know-how, in order not to facilitate competition.

Profits for an ABC company would be relatively small, probably never more than hundreds of thousands of €. The history of commercial mass production and sale of natural enemies spans a period of <50 years (Bolckmans 1999). In some areas of agriculture, such as fruit orchards, maize, cotton, sugarcane, soybean, vineyards and greenhouses, it has been a successful, environmentally and economically sound alternative for chemical pest control. Success of commercial BC is primarily dependent on the quality of the natural enemies, which are produced by mass-rearing companies (van Lenteren 2003a). Augmentative, commercial BC is applied on 0.16 million km^2 worldwide, which is 0.4% of land under cultivation. Today, more than 170 natural enemy species are on the market for BC. Of all commercialised species of natural enemies, about 45% are of alien origin (van Lenteren and Tommasini 2003). Worldwide, some 30 larger (more than 10 people) commercial producers are active (Bolckmans 2008), of which 20 are located in Europe. In addition, some 100 small (2–10 people) commercial producers are active. The total market for

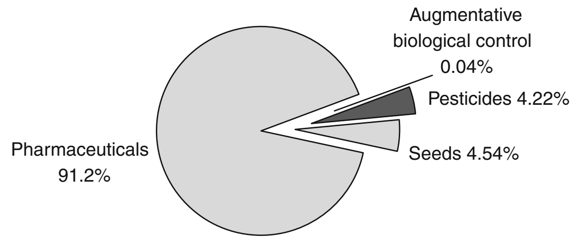

Fig. 2 Relative market value of selected biodiversity-related sectors

natural enemies at end-user level for greenhouses in 2008 was estimated at about € 150–200 million (Bolckmans 2008). The most important markets are Europe (75% of the market value), followed by North America (10%). Asia (8%), South America (5%) and Africa (2%) represent significant and growing markets. With an average net profit margin of around 3–5%, the total commercial ABC industry profit is under € 10 million per year. When we compare the monetary value spent on commercial BC (€ 200 million) with the € 22,230 million spent on chemical pesticides (Crop Life International 2008), the € 23,900 million spent on seeds (Laird and Wynberg 2008) and the € 480,000 million spent on pharmaceuticals (calculated from data in Laird and Wynberg 2008), we may conclude that ABC is a relatively small activity with very modest profits (Fig. 2). Given this situation, the scope for monetary benefit sharing is very limited, and concentrating on non-monetary aspects of benefit sharing such as joint research and capacity building is likely to pay greater dividends for potential source countries.

Summary of issues for BC in a financial benefit-sharing regime

- All countries can benefit from BC, and most do, but normally on a multilateral rather than bilateral basis;
- The impact of CBC is creating and sustaining public good (food security, food quality, reduced pesticide use, human health, especially for farmers and farm workers, invasive alien species control, protection of biodiversity, and maintenance of ecosystem services), and so benefits accrue to farmers, society and the country, rather than to the implementer;

- Those who implement CBC cannot gain any direct financial benefit from the process;
- CBC agents can spread accidentally or deliberately to adjacent countries that will also benefit (unless there are unwanted side-effects).
- The use of ABC can generate monetary benefits where the implementing agency is a commercial company, but these are relatively low so that it may be appropriate to concentrate on non-monetary benefit sharing, including capacity building, and research and technology sharing;
- Direct benefits of ABC accrue to the producers and the growers who buy and apply the BCA.
- Since there are no patents on organisms, BCAs are still freely available to anyone, including the source country.

A non-monetary ABS approach

With this paper, the IOBC Global Commission on ABS, on behalf of the BC community, has formulated a formal position on the ABS issue. In a wider context, there is a growing concern and consensus that it should be recognised that non-commercial academic research is not expected to generate monetary benefits, and therefore benefit sharing needs to focus on non-monetary benefits based on joint research and capacity building (Anonymous 2009; Biber-Klemm and Martinez 2006; DFG 2008; SCBD 2002). Broadly speaking the same arguments that apply to non-commercial research can be applied to BC. Amongst the actual or potential pragmatic benefits to the BC programme of working with local partners, BC practitioners will recognise:

- Local scientists' knowledge regarding collecting sites, local taxonomic expertise, local plants, farming methods, etc.;
- Assistance where language may be a problem;
- Interface with local authorities regarding permits and permissions;
- Straightforward arrangements for use of vehicles and field assistants, laboratory and field facilities;
- Well-informed local advice and back-up where security may be an issue for whatever reason;

Conversely, local partners can learn new skills and expertise by participating in surveys, participating in joint publications, and acquiring new biodiversity information on plant hosts, pests and natural enemies. Many national BC research groups appreciate the value of multilateral free exchange of BCAs arising from shared research, although some find that their participation in this process is restricted by ABS legislation. By participating, some of these local partners will become the leaders in developing BC options for their country in the future. These sorts of partnerships are already happening, in the spirit of the CBD, without necessarily having a formal ABS process and specific ABS agreements in place, so that in many cases benefits already accrue to source countries through shared research and capacity building (e.g. Case Studies 16, 25 and 26).

There is an active cooperative network of BC practitioners around the world, involving scientists working with government agencies, intergovernmental organisations, international agricultural research centres, universities, industry groups, etc. IOBC is one manifestation of this but much of the network operates at the personal level and based on the recognition that BC practitioners can assist each other on a multilateral basis and will try and do so (Case Studies 9, 11, 12, 16, 27).

Procedures for ABS need to be clear, straightforward and facilitate access for non-commercial research such as BC. It should be recognised that the multilateral free exchange process for BC contributes substantially to public good around the globe. Agreeing new processes should therefore recognise the immense value of using genetic resources for BC. At present, existing BC benefit sharing is based on joint research and capacity building, and there are no royalty mechanisms in place, but note that the developing Australian position provides a possible mechanism (see Annex 2 in the additional material).

The CBD (Article 8(h)) obliges all countries to "prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species". To help achieve this BC is an essential tool needed by all countries to tackle existing and future alien pest problems. Recent experience tells us that future introductions of pests and invasive species will occur when source countries fail to prevent the accidental export of these organisms, thus not meeting part of their obligation under the CBD. In spite of these almost inevitable failings, source countries can still support the implementation of Article 8(h) by facilitating access to BCAs from their countries—even when the source country for BCAs is not necessarily the actual source of the introduced species that is the target for the BC research programme.

The existing multilateral free exchange ethos and effective global networking of BC practitioners is a foundation on which to build an ABS protocol through international cooperation. A code of good practice should be prepared to guide this network, particularly with regard to non-monetary benefit sharing, and practitioners would be expected to follow this code.

Recommendations

The IOBC Global Commission on ABS (and the BC community to the extent that we have consulted colleagues) acknowledges and respects the concerns surrounding ABS and the sovereign rights of countries. ABS regulations should, however, recognise the specific features of BC if we want to avoid losing access to this essential pest management technology:

- Countries providing BCAs are also users of this technology;
- Many BCAs are exchanged without recoverable monetary value;
- BCAs cannot be patented, so can be used by anyone at any time;
- CBC information and to some degree ABC information is publicly shared;
- Indigenous/traditional knowledge has not been relevant;
- There are societal benefits for all, such as environmental and public health benefits, and reduction in pesticide use;
- BC is widely used in both developing and developed countries, often using the same BCAs;
- Most use of BC relates to food and agriculture.

In view of these specific features, we recommend:

1. Governments should build on the existing multilateral practice of free exchange of natural enemies for BC on a complementary and mutually reinforcing basis, which ensures fair and equitable sharing of the benefits of BC worldwide.
2. ABS regulations should support the BC sector, by facilitating the multilateral exchange of BCAs.
3. Countries are encouraged to have a single point of contact to facilitate survey missions, provision of information, institutional linkages and taxonomic support and provide advice on compliance with regulations for BC, including ABS.
4. ABS in relation to BC should normally be based on non-financial benefit sharing, e.g. capacity building, shared research programmes and/or technology transfer, as already practised by several organisations and the ABC industry.
5. A document describing best practices for ABS in relation to BC including guidelines for joint research that are equitable, but not restrictive, should be prepared and disseminated. BC organisations would be expected to follow these guidelines, which the IOBC Global Commission on ABS is willing to prepare when resources are available.
6. To improve transparency in the exchange of BCAs, mechanisms to establish and allow free access to database information on BCAs including source and receiving countries globally should be supported.
7. In the case of a humanitarian or emergency situation, governments should cooperate to fast track action, within FAO if appropriate.

Finally, we urge BC leaders in each country to join forces and get in touch with the ABS contact point for their country as soon as possible, and raise the issues surrounding the practice of BC and ABS, using local examples when appropriate, so their national delegates to the ABS discussions in 2010 are appropriately informed. Only if the BC community of practice gets involved in the discussions now, can they expect their needs to be taken into consideration.

Acknowledgments The authors would like to thank the following for their inputs, while noting that the use to which the information has been put in the report is the responsibility of the authors: Mic Julien, Bill Palmer and Ben Phillips (Australia), Antoni Bellotti (Colombia), Ding Jianqing (China), Phyllis G. Weintraub (Israel), Alvaro Toledo and Kim-Anh Tempelman (Italy), Johannette Klapwijk, Markus Knapp and Antoon J.M. Loomans (The Netherlands), Simon Fowler, Richard Hill and Hine-wai Loose (New Zealand), Josep Jacas and Alberto Urbaneja (Spain), Rebecca Murphy and Rob Tanner (UK), Robert H. Cowie and Lincoln Smith (USA), Marco d'Alessandro, Esther Gerber, Gitta Grosskopf, Patrick Häfliger, Tim Haye and Urs Schaffner (Switzerland), and the many other friends and colleagues around the world who have shared their views and given advice. The report to FAO from which this paper was developed was prepared with financial support from FAO and in-kind support from CABI and IOBC.

References

Anonymous (2009) Report of a workshop on Access and Benefit Sharing in non-commercial biodiversity research held at the Zoological Research Museum Alexander Koenig, Bonn, Germany, 17–19 Nov 2008. http://www.barcoding.si.edu/ABSworkshop.html

Biber-Klemm S, Martinez S (2006) Access and Benefit Sharing. Good practice for academic research on genetic resources. Swiss Academy of Sciences, Bern

Bigler F, Babendreier D, Kuhlmann U (eds) (2006) Environmental impact of invertebrates for biological control of arthropods: methods and risk assessment. CABI Publishing, Wallingford, UK

Bolckmans KJF (1999) Commercial aspects of biological pest control in greenhouses. In: Albajes R, Gullino ML, Lenteren JC, van Elad Y (eds) Integrated pest and disease management in greenhouse crops. Kluwer, Dordrecht, pp 310–318

Bolckmans KJF (2008) De insectenfabriek. In: Osse J, Schoonhoven L, Dicke M, Buiter R (eds) Natuur als bondgenoot: biologische bestrijding van ziekten en plagen. Bio-Wetenschappen en Maatschappij, Den Haag, pp 51–52

Cameron PJ, Hill RL, Bain J, Thomas WP (1989) A review of biological control of invertebrate pests and weeds in New Zealand 1874 to 1987. Technical Communication No. 10, CAB International Institute of Biological Control, CAB International, Farnham Royal, UK

CBD (Convention on Biological Diversity) (1993) Convention on Biological Diversity (with annexes). Concluded at Rio de Janeiro on 5 June 1992. United Nations—Treaty Series 1760(30619):142–382

Clausen CP (1978) Introduced parasites and predators of arthropod pests and weeds: a world review. United States Department of Agriculture, Washington DC (Agricultural handbook no. 480)

Cock MJW (1985) A review of biological control of pests in the Commonwealth Caribbean and Bermuda up to 1982. Technical Communication No. 9, Commonwealth Institute of Biological Control. Commonwealth Agricultural Bureaux, Farnham Royal, UK

Cock MJW, Ellison CA, Evans HC, Ooi PAC (2000) Can failure be turned into success for biological control of mile-a-minute weed (*Mikania micrantha*)? In: Spencer N (ed) Proceedings of the X international symposium on biological control of weeds, Bozeman, Montana, 4–14 July 1999. Montana State University, Bozeman, Montana, pp 155–167

Cock MJW, van Lenteren JC, Brodeur J, Barratt B, Bigler F, Bolckmans K, Cônsoli FL, Haas F, Mason PG, Parra JRP (2009) The use and exchange of biological control agents for food and agriculture. Commission on Genetic Resources for Food and Agriculture Background Study Paper No. 47. Food and Agriculture Organisation of the United Nations, Rome

Cox JM, Williams DJ (1981) An account of cassava mealybugs (Hemiptera: Pseudococcidae) with a description of a new species. Bull Entomol Res 71:247–258

Crop Life International (2008) Facts and figures—the status of global agriculture—2008. Crop Life International, Brussels, Belgium

DFG (Deutsche Forschungsgemeinschaft) (2008) Guidelines for funding proposals concerning research projects within the scope of the Convention on Biological Diversity (CBD). DFG-Form 1.021e—5/08. http://www.dfg.de/forschungsfoerderung/formulare/download/1_021e.pdf

Greathead DJ (1995) Benefits and risks of classical biological control. In: Hokkanen HMT, Lynch JM (eds) Biological control: benefits and risks. Cambridge University Press, Cambridge, pp 53–63

Greathead DJ, Greathead AH (1992) Biological control of insect pests by insect parasitoids and predators: the BIOCAT database. Biocontrol News Inf 13:61N–68N

Hajek AE, McManus ML, Delalibera Junior I (2005) Catalogue of introductions of pathogens and nematodes for classical biological control of insects and mites. FHTET-2005–05. Forest Health Technology Enterprise Team, Morgantown, West Virginia

Howarth FG (1991) Environmental impacts of classical biological control. Annu Rev Entomol 36:485–509

IOBC (2008) IOBC Global Commission on Biological Control and Access and Benefit Sharing. IOBC Newsl 84:5–7

IPPC (International Plant Protection Council) (1996) Code of conduct for the import and release of exotic biological control agents. International standards for phytosanitary measures no. 3, Food and Agriculture Organization of the United Nations, Rome, Italy, p 23

IPPC (2005) Guidelines for the export, shipment, import and release of biological control agents and other beneficial organisms. Food and Agriculture Organization of the United Nations, Rome, p 32 (International standards for phytosanitary measures no. 3)

Jinnah S, Jungcurt S (2009) Could access requirements stifle your research? Science 323:464–465

Julien MH, Griffiths MW (1998) Biological control of weeds. A World catalogue of agents and their target weeds, 4th edn. CABI, Wallingford

Kairo MTK, Cock MJW, Quinlan MM (2003) An assessment of the use of the code of conduct for the import and release of exotic biological control agents (ISPM no. 3) since its endorsement as an international standard. Biocontrol News Inf 24:15N–27N

Laird S, Wynberg R (2008) Access and benefit-sharing in practice: trends in partnerships across sectors. Secretariat of the Convention on Biological Diversity, Montreal, p 140 (CBD technical series 38)

Louda SM, Pemberton RW, Johnson MT, Follett PA (2003) Nontarget effects—the Achilles' heel of biological control? Annu Rev Entomol 48:365–396

Lynch LD, Hokkanen HMT, Babendreier D, Bigler F, Burgio G, Gao ZH, Kuske S, Loomans A, Menzler-Hokkanen I, Thomas MB, Tommassini G, Waage JK, van Lenteren JC, Zeng QQ (2001) Insect biological control and non-target effects: a European perspective. In: Wajnberg E, Scott JC, Quimby PC (eds) Evaluating indirect ecological effects of biological control. CABI, Wallingford, pp 99–125

Mason PG, Huber JT (2002) Biological control programmes in Canada, 1981–2000. CABI, Wallingford

Neuenschwander P (2003) Biological control of cassava and mango mealybugs in Africa. In: Neuenschwander P, Borgemeister C, Langewald J (eds) Biological control in IPM systems in Africa. CABI, Wallingford, pp 45–59

Neuenschwander P, Borgemeister C, Langewald J (2003) Biological control in IPM systems in Africa. CABI, Wallingford

Page AR, Lacey KL (2006) Economic impact assessment of Australian weed biological control. CRC for Australian Weed Management Technical Series 10, p 150

Parra JRP, Botelho PSM, Corrêa-Ferreira BS, Bento JMS (2002) Controle Biológico no Brasil: Parasitóides e Predadores. Editora Manole Ltda, Sao Paulo

SCBD (Secretariat of the Convention on Biological Diversity) (2002) Bonn guidelines on access to genetic resources and fair and equitable sharing of the benefits arising out of their utilization. Secretariat of the Convention on Biological Diversity, Montreal

van Lenteren JC (2000) Measures of success in biological control of arthropods by augmentation of natural enemies. In: Gurr G, Wratten S (eds) Measures of success in biological control. Kluwer, Dordrecht, pp 77–103

van Lenteren JC (ed) (2003a) Quality control and production of biological control agents: theory and testing procedures. CABI Publishing, Wallingford, UK

van Lenteren JC (2003b) Commercial availability of biological control agents. In: van Lenteren JC (ed) Quality control and production of biological control agents: theory and testing procedures. CABI, Wallingford, pp 167–179

van Lenteren JC, Bueno VHP (2003) Augmentative biological control of arthropods in Latin America. BioControl 48:123–139

van Lenteren JC, Tommasini MG (2003) Mass production, storage, shipment and release of natural enemies. In: van Lenteren JC (ed) Quality control and production of biological control agents: theory and testing procedures. CABI, Wallingford, pp 181–189

van Lenteren JC, Bale J, Bigler F, Hokkanen HMT, Loomans AJM (2006) Assessing risks of releasing exotic biological control agents of arthropod pests. Annu Rev Entomol 51:609–634

Waterhouse DF, Sands DPA (2001) Classical biological control of arthropods in Australia. Australian Centre for International Agricultural Research, Canberra (ACIAR monograph no. 77)

Wittenberg R, Cock MJW (2001) Invasive alien species: a toolkit of best prevention and management practices. CABI, Wallingford (on behalf of the Global Invasive Species Programme)

World Bank (2009) Data and statistics. Country groups. http://go.worldbank.org/D7SN0B8YU0 (accessed 7 May 2009)

Yaninek JS (2003) Cassava green mite in Africa—a unique example of successful classical biological control of a mite. In: Neuenschwander P, Borgemeister C, Langewald J (eds) Biological control in IPM Systems in Africa. CABI, Wallingford, pp 61–75