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Impact of Access and Benefit Sharing implementation on biological control genetic resources

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Abstract The third objective of the Convention on Biological Diversity, the fair and equitable sharing of benefits arising out of the use of genetic resources was further developed when the Nagoya Protocol on Access and Benefit Sharing came into effect in 2014. Interpretation of how this agreement is being implemented is wide-ranging and there are implications for biological control. A survey of biological control workers indicated that while some countries have facilitated access to biological control genetic resources, requirements in other countries have impeded biological control implementation. There was consensus that benefits to provider countries should be in the form of supporting local research communities. There was also agreement that the free use and exchange of biological control genetic resources has provided benefits to the global community, including to both providers and recipients of the agents. It is recommended that consideration of the free use and exchange principal should be a key element of Access and Benefit Sharing measures for the future.

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Introduction

Biological control genetic resources are biological control agents, defined as living organisms or viruses that induce an action (e.g., population density reduction) against target organisms that cause harm to humans or their resources (Hoddle et al. 2008; Heimpel and Mills 2017; Stenberg et al. 2021). A wide range of organisms are used as biological control agents (Sforza 2021) including herbivores, parasitoids, predators and pathogens. Biological control agents are employed using several strategies. Conservation biological control involves the preservation or enhancement of the existing natural enemy community by habitat management (Zaviezo et al. 2021). It is a public good strategy that provides medium- to long-term natural benefit with investment by an individual grower or local community. Classical (importation) biological control involves the introduction of natural enemies from the area of origin to areas invaded by non-native problem species with the goal to establish self-sustaining natural enemy populations, that disperse to wherever the target occurs (Hoddle et al. 2021). It is a non-commercial public good strategy that provides a long-term and often sustainable solution (Mason et al. 2021). Typically, investment is made by the user country for exploration, risk assessment, mass rearing, release and assessment of impacts. An environmentally safe and effective agent can be freely shared with other countries with the same invasive species problem. This multilateral exchange has been practiced since the earliest days of biological control in the 18th century, since many countries are both providers and users of biological control agents (Cock et al. 2009, 2010). This principal has increasingly encouraged international collaborations (Brodeur et al. 2018). Government agencies from developed nations have been the main drivers of this public good work which can involve significant long-term investment (Cock et al. 2009).

Augmentative biological control involves the mass release of living natural enemies often in confined environments invaded by non-native and native problem species with the goal to establish a temporary presence of an agent in the environment (van Lenteren et al. 2021). It is a commercially driven strategy that offers a short-term solution. Investment is made by private companies who discover, evaluate and mass produce the agent which is then sold as a commercial product.

Once a biological control agent has proven to be effective it can be used wherever the problem species occurs once required biosafety measures have been established, including those of the provider country. Furthermore, during emergency situations, such as when a keystone species is at risk of extinction or food security is threatened, fast tracking classical biological control can contribute to preventing irreversible harm (Cock et al. 2009), thus providing a public good service to society. Commercial biological control agents may also play an important role during emergencies (Mason et al. 2021).

The 1993 Convention on Biological Diversity (CBD) and particularly its third objective, fair and equitable sharing of benefits arising out of the utilization of genetic resources has resulted in a wide array of reactions from impacted sectors. These include commercial (Michiels et al. 2021) and non-commercial research (Rourke 2018), primary production agriculture for food (Commission on genetic resources for food and agriculture 2016; Welch et al. 2017) and medicine (Schindel et al. 2015), biodiversity and conservation (Neumann et al. 2018; Prathapan et al. 2018) and pest management using classical biological control.

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The Nagoya Protocol on Access and Benefit sharing (NP) is the instrument that further develops access and benefit sharing (ABS) obligations set under the CBD. The NP came into force October 2014 and currently there are 155 party signatories of which 137 have also formally ratified it. Parties to the NP (https://absch.cbd.int/en/about/countryProfiles) can choose to develop a legal framework to ensure fair and equitable sharing of the benefits that arise from the use of the genetic resources they provide. If that were the case, access to genetic resources for their use is subject to the prior informed consent of the Party providing such resources (NP article 6.1) and benefits arising from their utilization are to be shared in a fair and equitable way upon mutually agreed terms (NP article 5.1). However, participating countries were not provided with guidance for developing legislation on ABS, thus interpretation on what is equitable sharing and what are benefits is likely to vary widely. Although still early on in the process, there has been inconsistent implementation of NP legislation and this has resulted in much confusion (Silvestri et al. 2020; Mason et al. 2021). Despite the CBD formally recognising that biological control "can be an effective measure to manage already established invasive alien species" (Decision COPXIII/13) and publishing a technical report on this approach (Sheppard et al. 2019), the NP has become one of the most important regulatory challenges facing the practice of biological control (Barratt et al. 2018).

The International Organization for Biological Control (IOBC) Global recognised in 2008 that ABS of genetic resources would potentially have wide ranging implications for biological control. In response, IOBC Global established a Commission on Biological Control and ABS to report to the Food and Agriculture Organization (FAO) Commission on Genetic Resources for Food and Agriculture (Cock et al. 2009). The report acknowledged the risk to biological control practice posed by ABS and recommended that biological control, being a largely non-commercial, public good activity should be exempt from ABS regulations, or at least subject to a simplified process. However, there may be a condition set out for a biological control agent that is subsequently sold as a commercial product. Gourlay et al. (2013) noted that biological control practitioners in each country should proactively have input into their national regulation, not only on implications for biological control, but also other non-commercial research activities such as taxonomy. Coutinot et al. (2013) described the problems experienced in the Euro-Mediterranean region, Argentina, and Brazil including the lengthy and complex steps required to obtain permits for access and exchange of natural enemies. These authors proposed a simplified framework for classical/importation and augmentative biological control whereby a permit issued by the donor country for export of biological control agents and a second permit issued by the country receiving the agents would comply with ABS requirements.

Implications of ABS procedures and regulations

Access to and use of biological control genetic resources could be affected by ABS procedures and regulations in several ways. One scenario could be that a country or subnational jurisdiction does not allow access to their biodiversity, effectively totally banning access to biological control agents. A situation where this might be imposed is when elements of their biodiversity are considered endangered. There are no known examples where an invasive alien species has such status in its area of origin, thus associated biological control agents are unlikely to be on such a list.

Secondly, it is more likely that access is allowed but the process is excessively bureaucratic (Silvestri et al. 2020). Historically, collection and export permits have been required when surveys were conducted in the area of origin for natural enemies (arthropods, microorganisms) associated with a species invasive in other countries. These requirements and the associated processes are well established in some countries and allow the provider country to document what species are being sourced and sent abroad. Implementation of ABS measures has increased the complexity of the bureaucracy that must be negotiated—the applicant must register with different government agencies (federal, state/provincial, conservation), then proceed through numerous processes such as Prior Informed Consent (PIC), Mutually Agreed Terms (MAT), and must negotiate a benefit package with the provider country, as well as obtaining collection and export permits. Examples of these types of challenges were outlined by Silvestri et al. (2020), Ivey et al. (2023) and Mc Kay et al. (2023). Furthermore,

where national regulations and procedures are yet to be put in place, or are new and responsibilities and procedures are yet to become well established have the potential to delay access to, increase the costs for, or even prevent the sharing of biological control agents, at least temporarily.

A third context of implementation of ABS procedures and measures is the increased costs associated with each step of the process to obtain access to biological control agents. Funding for biological control projects is often limited and may be unable to absorb the additional fees imposed for obtaining PIC, establishing MAT and negotiating benefits to the provider country. These costs are likely to be different for each biological control project, further complicating the funding required and delaying project initiation.

Weed biological control researchers at the Centre for Agriculture and Bioscience International (CABI) (https://www.cabi.org) have documented the measures that they have had to implement to overcome difficulties with access to biological control agents (Hinz et al. 2018) and stressed the importance of exercising due diligence (Smith et al. 2018) regarding ABS to guarantee that classical biological control can remain a viable tool for invasive plant management (Weyl et al. 2023). Similarly, Silvestri et al. (2018, 2020) described difficulties in collecting and accessing genetic resources for weed biological control and inefficiencies in the transfer and/or exchange of genetic resources between international collaborating partners in the absence of separate and simplified measures for access to genetic resources for non-commercial, compared with commercial research. Smith et al. (2018) commented that apart from having to deal with the myriad of different mechanisms countries are formulating, it is often difficult to simply find, and obtain responses from the National Focal Points or Competent National Authorities of each country. This results in considerable time wasting and frustration.

A recent account of ABS issues pertaining to plant genetic resources for commercial purposes notes that plant breeding and the exchange of germplasm between countries is vital to global food security and provides socio-economic and environmental benefits (Michiels et al. 2021). They argue that companies having to deal with the complexities of ABS is likely to result in unintended negative consequences for food and agriculture. The authors conclude that a fundamental review of ABS should be considered, and in so doing, it would be appropriate to question the extent to which ABS has so far contributed to CBD objectives, what value has ABS delivered via benefit sharing; and the extent to which biodiversity conservation has been supported by ABS thus far (Michiels et al. 2021).

Prathapan et al. (2018) argued the NP will likely delay and limit knowledge on biodiversity and its conservation including the international capacity to understand emerging infectious diseases. They were also concerned about potential increased threat of scientist imprisonments and difficulties to maintaining scientific biological reference collections and exchanging material between institutions. Neumann et al. (2018) more optimistically noted that like other international treaties, the uncertainties around implementation of the NP will decrease, and that 'common sense will prevail'. They feel that this could come about via strong input from scientific communities, and the development of internationally accepted ABS management tools, such as best-practice guidelines, which indeed the IOBC Commission on Biological Control and ABS have proposed for invertebrates (Mason et al. 2018). A general best practices framework for biological control genetic resources was provided by Mason et al. (2021).

IOBC questionnaire

The (IOBC) Global Commission on Biological Control and Access and Benefit Sharing conducted a survey in 2021–2022 to examine the perception of impacts by the Biological Control Community of Practice about ABS rules (Supplementary information). The survey targeted the biological control community, including providers and recipients of biological control agents, those assessing risk, and those releasing and conducting follow up monitoring. The survey was available at the IOBC website from July 2021 to June 2022. The target audience was informed of the survey via the IOBC website and the global newsletter. The survey consisted of 12 questions and responses were anonymous (no personal or organizational information was requested). The information gathered aimed to provide a baseline on the level of understanding by biological control researchers and practitioners of ABS and measures in place. This will

guide IOBC and the Global Commission on a path forward including understanding experiences and approaches, refining best practices, developing a common position, and providing advice to governments and international organizations (e.g., FAO Commission on Genetic Resources for Food and Agriculture, Convention on Biological Diversity).

Overall, there were 31 respondents to the questionnaire which was lower than expected considering the number of biological control workers globally. However, this may be explained by the fact that most people working in biological control are involved in implementation and post-release activities rather than accessing new biological control agents. Furthermore, those biological control researchers and/or practitioners not aware of NP were unlikely to have completed the survey. An analysis of the responses to the questions is presented below.

Question 1: What level of knowledge about the Nagoya protocol do biological practitioners have?

Survey respondents had at least some knowledge of the NP and ABS with the most (35%) having moderate knowledge. Several respondents who indicated 'some' knowledge (26% individuals) commented that their understanding was that the NP creates problems for international research by limiting movement of biological control agents, that no institutes can give advice on how to handle this correctly or that they have only a basic understanding. Respondents with 'moderate' knowledge (35%) commented that they had learned about the NP through presentations at conferences or through experience gained when exporting biological control agents. Among those with 'good' knowledge (26%) one commented that she/he had read the CBD and tried to apply and/or work around the NP and another gained knowledge through export of biological control agents. Respondents with 'abundant' knowledge (13%) indicated that they have been dealing with ABS matters concerning the CBD for many years, including before the NP came into force.

Question 2: What are the barriers to progress of projects on classical or augmentative biological control of weeds or pest arthropods?

Respondents were asked to select up to three of the eight options given or note an additional barrier impeding progress of biological control agents (Fig. 1). Each option was indicated by at least 5% of respondents with a lack of simplified procedures most often indicated (21.9%) and staff turnover the least indicated (5.5%). Negotiating PIC and MAT, scattered requirements, no/unclear regulations, political issues, redundant requirements, and insufficient capacity within the responsible government agencies were each indicated at similar levels (8.8–11.0%). Additional barriers were frequently indicated (11%) and included such things as people in the source country being unmotivated to assist, the use of different criteria by subnational and national jurisdictions (i.e., redundant or conflicting requirements), mistrust of the intentions of researchers, an inability to know where to start or whom to contact. Two respondents commented that all of the barriers listed occurred to some degree.

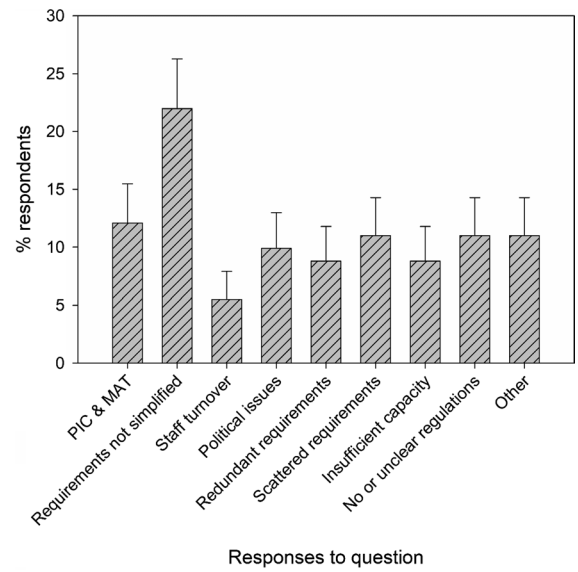

Fig. 1 Barriers to progress of projects on classical or augmentative biological control of weeds or pest arthropods created when access and benefit sharing measures are implemented (IOBC survey Question 2): *PIC* Prior Informed Consent; *MAT* Mutually Agreed Terms. Error bars represent SE

Question 3: Examples of where efficient administration of the Nagoya protocol assisted you to deliver your biological control project

Respondents were asked to name countries where these positive experiences applied. Of the respondents ten named countries that they had engaged with, including Argentina, Bolivia, Brazil, Germany, India, South Africa and Switzerland, all parties to the NP, and Paraguay which is a non-party. They were asked to indicate which of the following options were experienced (more than one could be indicated and the numbers of respondents for each are shown in parenthesis):

(1) Correct information on procedures for PIC and/or negotiating MAT was easily accessible and concise (3)
(2) Legal requirements and procedures for the access to genetic resources to pursue non-commercial research, such as classical biological control of weed or pest arthropod programs were simple and easily understood (6)
(3) The official department dealing with utilization and export of biological control agents remained consistent and even with changeover of staff, new bureaucrats ensured efficient management of the processes required (i.e., provincial/national focal points and competent national authorities) (3)
(4) Access to genetic resources was encouraged for improved agricultural production and protection of biodiversity (0)
(5) Procedures focused on the intention of the NP "promoting the use of genetic resources and associated traditional knowledge" and bureaucrats assisted in achievement of this aim (1)
(6) Access and Benefit Sharing regulations and decision-making power were consolidated in a single national entity (1)
(7) There was sufficient institutional capacity to efficiently manage access to potential biological control agents (5)
(8) Regulations were clear and easily accessible (3)
(9) Other (6)

It is noteworthy that no respondent indicated that access to genetic resources was encouraged for improved agricultural production and protection of biodiversity.

Several respondents provided comments on how they were facilitated. For example, it was noted that in Brazil, although the process was not simple and easy to understand all forms are online, including a user manual, and that once submission is completed, the license is approved in two or three weeks. Another respondent noted that CABI played the role of intermediary in obtaining biological control agents. A third respondent commented that a country partner facilitated the process to obtain biological control agents in India. This same individual noted that most EU countries have opted not to control access to genetic resources (including biological control agents), and that CABI is well positioned to provide advice on ABS measures globally, having a clear policy and country-specific best practices. Respondents who indicated 'other' provided comments, including that they were not able to export biological control agents from the intended source country and instead collected in a neighboring country where the proper paperwork and permits could be obtained, and that they were assisted by in-country contacts in navigating the complexities of obtaining potential biological control agents for study.

Question 4: Unintended consequences of ABS national regimes have impacted most on research and practice on classical or augmentative biocontrol of weeds or pest arthropods

Twenty-nine individuals provided responses. Among the six options, the most common consequence indicated was delay of the project (35.6%), followed by a change in the source country (20.3%), project cancellation (16.9%), delay of agent releases (15.3%), loss of project funding (11.9%), and other (15.3%). Respondents providing comments noted that ABS benefit requirements added costs to the project, political measures impeded access, or adjustment of the work program in order to not create problems, resulting in a project strategy that was not straightforward. It was further noted that relocation of projects was the result of the inability to obtain permits in a preferred source country.

Question 5: Examples where projects have taken heed of the intention of the Nagoya Protocol and have progressed in a timely manner

Of the 31 respondents 14 named countries that they had engaged with to access biological control

agents, among these Argentina, Brazil, Germany, India, Indonesia, Morocco, South Africa, Switzerland and Uruguay are parties to the NP and Australia, Paraguay and the USA are non-parties, although Australia and the USA have their own ABS requirements. Respondents indicated most frequently that the source country facilitated access (30%), followed by no project delays (19%), other factors were involved (19%), the project moved forward (15%), no release delays (9%), and funding was not impacted (9%). Several individuals made comments where the intention of the NP was considered. For example, in South Africa an explanation was given that the NP relates to that country's regulations and that export activities of non-commercial nature only require collection and import permits enabled timely delivery of biological control agents. Another respondent commented that projects are proceeding despite assumed non-compliance with NP. Others indicated that obtaining permits for projects with CSIRO (and New South Wales) in Australia were not affected by procedures (ABS-type requirements are in place), and that the process for importing biological control agents from Germany was straightforward. Also noted were the roles of partners such as CABI, the Indian Council for Agricultural Research (ICAR) and the Foundation for the Study of Invasive Species (FuEDEI) (Argentina) in facilitating access to biological control agents. In one case where the recipient country was not a signatory to the NP there was uncertainty about how to proceed but access was facilitated by moving forward as if both Morocco and Australia were signatories. There were also negative comments indicating that ABS has made work in some countries nearly impossible, and that access moved forward only in countries where there are no access controls in place.

Comments by those indicating that 'other' factors were involved in taking heed of the intent of the NP (19%) included that the sharing of insect specimens with researchers outside the country for advanced taxonomic studies with formal approval from the National Biodiversity authority was possible, although sharing of live insects for biological control has still not happened due to unclear regulations. This meant that projects ultimately resulted in export facilitation but with years of hiatus and was hugely laborious administratively. Another individual commented that insects have been collected and exported successfully from the USA (non-party to NP) and Uruguay (party to NP).

Question 6: Past and current level of involvement to import potential biological control agents from provider countries

A total of 28 countries were named by the 25 individuals responding to this question. Of the responses, 50% indicated that a current project was underway and another 13% indicated that a project is planned (Fig. 2). The 19 provider and receiving countries with current or planned projects included Argentina, Australia, Benin, Brazil, Chile, China, Ghana, India, Italy, Madagascar, Morocco, Paraguay, Republic of Korea, South Africa, Switzerland, UK, USA, and Uruguay. The highest number of current or planned projects were in Argentina (seven and two, respectively), followed by South Africa (five and one, respectively), the USA (three and two, respectively), Switzerland (four current projects), Brazil (two and one, respectively), China (three and two, respectively), and India (two current projects). Single projects were current or planned in the other countries. A further four countries, France, Japan, Russian Federation and Zimbabwe, were mentioned as being of interest for future projects.

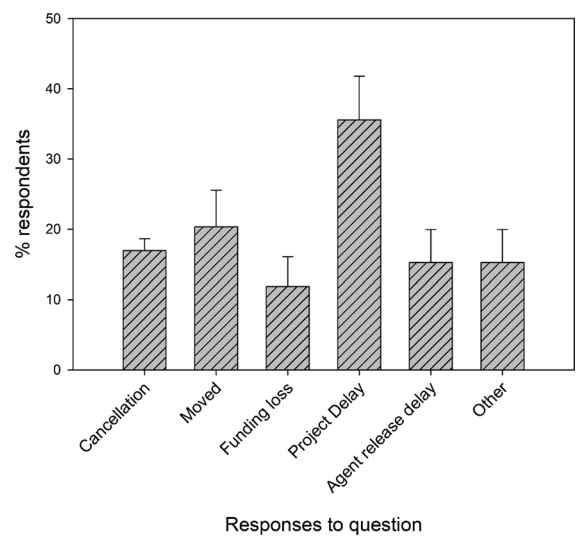

Fig. 2 Past and current level of involvement to import potential biological control agents from provider countries (IOBC survey Question 6). Error bars represent SE

Question 7: Influence of knowledge of, or experience with national policies to control access to genetic resources on involvement to import biological control agents from provider countries

Only ten individuals provided responses, indicating they had some knowledge of ABS national policies controlling access that influenced their involvement to import biological control agents from 14 provider countries. Projects were proceeding in 52% of the cases involving eight provider countries: Argentina, Brazil, Germany, Morocco, Pakistan, South Africa, Switzerland and Uruguay. Five individuals indicated that they had some or good experience with ABS measures that influenced their involvement to import biological control agents from eight provider countries. Projects were proceeding in 50% of the cases, in Argentina, Brazil, Germany, Switzerland and Australia.

Question 8: For present and past projects, level of involvement (either personal actions or sending funds), and level of influence from the Nagoya protocol

Twelve individuals provided responses for 23 projects in 14 provider countries, including Argentina, Brazil, China, Germany, France, Indonesia, Morocco, Pakistan, Republic of Korea, Russia, South Africa, Switzerland, USA and Uruguay. Results are summarized in Table 1. For most (14) projects respondents were not involved in pre-project consultation with indigenous peoples, local communities or ethnobotanists about known plant–insect or pathogen interactions. It is unclear whether this is because local partners were involved, or the activity was not done. In two projects, one in Brazil and one in the USA respondents indicated personal involvement in pre-project consultations. Respondents were involved in all stages of the biological control projects although they mainly provided funding for collaborators to conduct surveys for natural enemies, host range testing in the country of origin, and their export to the recipient country (importation into designated quarantine facilities for host range and efficacy studies). Funds were provided to collaborators for at least one activity in projects in all countries except the USA. For projects involving Russia and the USA categories for influence of the NP were marked but it is unclear whether these countries were providers or recipients of the biological control agents.

National ABS regulations did not impede any of the activities associated with the biological control projects noted (Table 1). In most cases they had no influence but where they did, the work proceeded. There was a single case where these regulations prevented work on host range testing in the country of origin.

Table 1 Number of respondents indicating their level of involvement (either personal actions or sending funds) for past and present projects with any provider country and the level of influence from the Nagoya Protocol on project status (IOBC survey Question 8)

Stage of program	Scientist involvement			National regulation influence		
	None	Personal involvement	Funds/collaboration	None	Influence–work proceeding	Influence–work not proceeding
Pre-project consultation with indigenous people, local communities or ethnobotanists about known plant–insect or pathogen interactions	14	2	6	16	6	0
Survey for natural enemies	1	6	16	11	12	0
Host range tests in country of origin	6	2	15	17	5	1
Import natural enemy/enemies to designated quarantine for host range tests and efficacy in quarantine	1	8	10	6	13	0
Additional shipment of agent(s) to quarantine for mass rearing	10	5	4	14	5	0
Release agent(s) into new environment	11	7	1	14	4	0

Question 9: For present and past projects, have benefits been made available to the provider country in exchange for access to and use of a biological control agent?

The definition of 'benefit' was left open to interpretation by respondents. Of the 25 individuals who responded three indicated that no benefit was provided to the source country. Eight indicated that benefits were provided and another ten did not indicate in the option column but their comments strongly suggest that benefits were provided to the source country.

The type of benefit provided varied from providing financial support directly to collaborators to non-monetary benefits such as co-authorship on manuscripts. It is unlikely that these types of benefit would be negotiated under national ABS processes. Probably these would be negotiated directly with collaborating partners in the providing country as has been the tradition before the NP came into force.

Question 10: Type of benefit the provider country should receive

This question provided several options that respondents could select under monetary and non-monetary categories. It should be noted that to a certain extent monetary and non-monetary benefits overlapped in the responses. To clarify, the context for monetary benefits was payment to the provider country while that for non-monetary was direct support (including financial) to collaborators for activities related to biodiversity and biological control. Among the 29 respondents 15 individuals indicated that the best option for biological control projects was provision of non-monetary benefits and 13 indicated that monetary benefits should be provided. A single individual indicated that no benefit should be provided.

Non-monetary benefit options included: (1) support of scientists in the provider country (e.g., joint publications), (2) training of provider country personnel (students, non-scientific staff), and (3) other. Responses indicated options (1) and (2) almost equally (40.3% and 37.3%, respectively) while (3) was indicated in 22.4% of the responses. Comments suggested that these benefits could be in the form of reciprocal assistance (e.g., support work on developing new agents in country 1 for use against target A in country 2 and for developing new agents in country 2 for use against target B in country 1), participation in field explorations, joint submission of proposals, inviting provincial/national regulators to field release events of biological control agents in the recipient country, sensible compensation to help the provider country use the agent, mutual exchange of biological control agents at no cost (other than collection, laboratory, and shipping costs), sharing biodiversity knowledge, free exchange of biological control agents, specifically if it relates to conservation biological control, travel for scientists between countries for academic/research exchange (e.g., internships/fellowships), presentations, media releases, advancing sustainable development goals through provision of the know how (information) and access to the biological control agents, investment in local infrastructure (e.g., provision of microscopes, minor lab renovations), consolidation of national collections with voucher specimens, capacity building, and facilitation of project development in the provider country for reciprocal exchanges as required. One individual commented: "My fear with monetary compensation is that the authorities will almost certainly ask for ridiculous sums, based on the normal revenue levels of pharmaceutical and agricultural companies. For biological control, cash payment should be avoided at all cost".

Monetary benefit options in the questionnaire included: (1) one-time cash payment, (2) annual cash payment in perpetuity, (3) annual cash payment for a specified period, (4) per release cash payment, and (5) other. Responses indicated options (1) and (2) most frequently at 31.3% and 25%, respectively while 37.5% of responses suggested other options. A single individual indicated per release cash payment and commented that this should be done when the biological control agent is used for business (commercially sold). Option (3) was not indicated by any respondent. Comments included that payment has to depend on several factors. For instance, if the potential agent will have commercial use or not; cash (per release) may be an option, but transmission of knowhow should be preferable; is related to turnover of product (royalty fee style); will depend on the projects, as some will have financial support while other do not, could be each year for the duration of the project. One individual noted that the release of agents is not profit making.

Other comments made in the monetary benefits question were directed towards payments: to technicians/researchers/students for the length of time they are collecting, breeding and exporting the agent if not a one-off collection; for duration of the project; from research grants over five years for equipment and supplies and to support scientists and students, although the length of research grants is variable; as remuneration for collaborative staff time, resources, etc. to facilitate the project for its duration. One individual wondered how annual payments, royalties, or similar income generating strategies could be supported once the agent is released for classical biological control.

Other comments for this question related more to non-monetary benefits. For example, provision for bilateral exchange of biological agents, authorship on scientific papers, acknowledgements for assistance with project and giving the provider country access to information on the results on the effect of biological control agent releases.

Question 11: Consideration of an alternative approach to bilateral negotiations

This question asked respondents if they would consider an alternative approach to bilateral negotiations (i.e., between provider and recipient only) such as a multilateral approach that would share the benefits among a provider and multiple recipients and provide a single point of access. Of the 22 individuals who provided a response, 16 indicated they would consider an alternative approach to bilateral negotiations while four indicated they would not. Those who would consider an alternative to bilateral negotiations favoured a multilateral approach (see Mason et al. 2023b). Reasons provided for this included that:

(1) A multilateral rather than a bilateral approach seems to be more appropriate/suitable considering that the free multilateral exchange of biological control agents has been a foundational aspect of the biological control global network.
(2) It would benefit more countries and therefore be more beneficial overall.
(3) It would potentially help the progress of biological control of alien invasive weeds.
($) This approach seems reasonable, but would be most agreeable if multiple recipients were not simply from the same country but from multiple countries.
(5) A multilateral approach should be considered if the species to be provided would benefit more than one country.
(6) It makes sense, though it is not clear how to gain binding participation by some countries.
(7) A multilateral system could be established to enable countries to sign up to the principle of open access and sharing knowledge and technology to facilitate the biological control of pests and diseases to reduce crop and agricultural losses.
(8) A multilateral approach would be promoted for non-commercial research and bilateral negotiations only need to begin if commercial development is allowed.
(9) Several interested countries (biological control practitioners) banding together to support in-country research, outreach, and training would strengthen and expand biological programs in multiple locations, including the source country.
(10) A multilateral agreement on the use and exchange of biological control agents would enable simplified procedures for access and benefit sharing.
(11) Problem species targeted for biological control tend to be present in more than one country and agreements that allow use of a biological control agent in all countries affected would allow timely use wherever the problem species occurs.
(12) In cases where bilateral agreements have finally been achieved, it has also been the case that third party agreements need to be sought to allow biological control agents to be released in the invaded range (where intermediate recipients are funded to undertake the work) or to allow wider use where other countries are affected by the same invasive species.
(13) Benefits should be shared with multiple recipients where possible.

Respondents who were not in favour of an alternative to bilateral negotiations reasoned that: “negotiations among more actors would only make the process more difficult and longer”; “a multilateral approach could be not of interest to the provider country when mul-

tiple recipients are present"; "this will quickly get way too complicated with too many competing interests"; and "each scientist/institution must deal with their own bureaucracies and indirect costs from grants".

Question 12: Other comments

Additional comments were provided by eight individuals and included a number of recommendations. These are summarized below:

(1) Either bilateral or multilateral, simplified measures for the access to and exchange of biological control agents should be adopted.
(2) Consideration to exempt biological control activities from the scope of the ABS regime.
(3) A clearer discrimination between research only (with no monetary interests) and commercial activities, including the proviso that strictly research projects should be enabled through non-bureaucratic measures and easy access to needed genetic resources with the only restrictions that every research outcome has to be published and data made available in an open resource repository.
(4) That benefits need to be shared that arise from the use of genetic resources and up to the point of placing a product on the market the benefits that should be shared are the information generated and the genetic resources themselves.
(5) If the research is purely for commercial purposes to enable a product to be placed on the market then the benefits should become monetary as reflected in Brazilian law and process.
(6) Regulations and measures implemented should consider the public good aspects of classical biological control.
(7) Collaboration with personnel in exporting countries to negotiate the bureaucratic process has facilitated access to biological control agents but this is not sustainable.
(8) A reliable, overarching global point of access or treaty for benefit sharing by biological control practitioners, though challenging to achieve, would make the situation better.

Two individuals commented on the questionnaire. One stated "While I am very excited that it looks like things are moving along and for the better, it seems like this questionnaire is thinking more about the importing country than the exporting country. Since I am more involved in the latter, I think we still have a long way to go".

Main survey findings

Although the number of survey respondents was lower than expected, the information gathered provided key points to guide the IOBC and the Global Commission on a path forward to influence development of ABS requirements that consider the special status of biological control. Individuals who responded had at least some knowledge of the NP and ABS with most (75%) having moderate to abundant knowledge. There were a variety of ABS challenges impeding progress in biological control projects of which 52.7% related to sorting out how to address ABS measures (requirements that were not simplified, redundant, scattered or unclear). Confusion about ABS requirements also resulted in consequences, mainly delay of the project or release of the agent. This also resulted in some projects being relocated to countries where the ABS measures were more straightforward or to countries without ABS measures. For a number of countries positive experiences with ABS requirements and procedures were noted. For instance, most European countries do not restrict access to their genetic resources, and the ones that do (e.g., France) have clear measures in place. Another example is South Africa, where export of genetic resources for non-commercial use only requires collection and import permits enabled timely delivery of biological control agents. In general, for these countries requirements and procedures were simple and easily understood, management of the processes required for use and export of biological control agents remained consistent, assistance provided focused on the intent of the NP, decision making was consolidated in a single national entity, and there was sufficient institutional capacity to efficiently manage access to potential biological control agents. Facilitation by provider countries enabled biological control projects to proceed in a timely manner. There was ongoing interest in

pursuing biological control projects with provider countries and there were ongoing or planned projects in 19 countries. Knowledge of or experience with national ABS policies had an influence on decisions to proceed with projects and in about 50% of cases biological control projects were moving forward. Most respondents were not involved in pre-project consultation with indigenous peoples or local communities and mainly provided funding for collaborators in the provider countries to conduct surveys for natural enemies, host range testing in the country of origin, and their export to the recipient country. For past and present projects, national ABS regulations did not impede any of the activities associated with biological control, although they did have influence in some cases.

Approximately half of respondents (52%) indicated that benefits to the provider country for access to biological control genetic resources should be non-monetary or direct financial support to collaborators rather than direct monetary payment to government. Examples of non-monetary benefits include assistance to build capacity in provider countries, train personnel, build scientific partnerships and the free exchange of biological control agents. Historically, monetary benefits to the provider country have been in the form of provision of funding to support local student bursaries, post-graduate degrees, post-doctoral researchers, international conference attendance and capacity building (laboratory upgrades, purchase of laboratory equipment and supplies), financial support to conduct the research, collection and shipment of potential agents (i.e., monetary but direct support to researchers). If a cash payment to the provider country was required, respondents indicated that it should be a one-time or annual payment.

Most respondents (80%) indicated that an alternative approach to bilateral negotiations is preferable. Most considered that a multilateral approach would support the ideal of providing benefits to as many countries as possible through the principle of free use and exchange of biological control agents. Those who did not support an alternative approach were concerned that a broader approach would impose greater bureaucracy and less cooperation from a provider country.

The survey was designed to obtain information on ABS primarily from the perspective of those obtaining biological control agents from a source country. However, exporters of biological control agents could also respond and some provided comments suggesting that ABS has also been a problem for export of agents. Facilitating export of natural enemies would certainly be an important aspect of any measures for accessing biological control agents.

Free use and exchange of biological control genetic resources

The principles of the free use and exchange of biological control genetic resources were outlined by Cock et al. (2009, 2010). Essentially, once a biological control agent has been established and found to be effective in a receiving country it is shared with other countries experiencing the same pest or weed problem. These principles should qualify for special consideration in times of emergency (present or imminent) to address threats or damage to human, animal or plant health as noted in Article 8.b of the NP (CBD 2011).

Of importance is that investments to explore for and develop biological control agents has been by wealthy countries such as the USA, Australia, South Africa, as well as consortia (e.g., CABI member countries, International Institute of Tropical Agriculture, South Pacific Commission). These investments result in the discovery of agents that are comprehensively assessed for safety and efficacy (Cock et al. 2009; Hoelmer et al. 2023). Less developed countries benefit in that they do not need to invest in finding and developing an agent because all countries can use the agent at no cost with no fees for access to the agent (Cock et al. 2009). Furthermore, the biological control agent can be sourced or naturally spread from wherever it is introduced, for example neighbouring countries can provide founder populations of a well-adapted agent for biological control of an invasive alien species that has spread to adjacent countries.

Free use and exchange of a biological control agent leads to widespread control of a target and is in the best interests of the global community, reducing the potential for re-invasion. Furthermore, countries that provide biological control agents almost always are frequent users of biological control and it is in their national self-interest to ensure the free multilateral

exchange of these species (Cock et al. 2010). It should also be noted that countries that are the origin of target invasive alien species are the most likely sources of the biological control agents required to suppress populations of these species (Cock et al. 2009; Mason et al. 2021).

There are many examples of biological control agents that have been freely shared. Among the most famous are *Novius cardinalis* (Mulsant) (Coleoptera: Coccinellidae) sourced from Australia and New Zealand to control cottony cushion scale, *Icerya purchasi* Maskell (Hemiptera: Monophlebidae), originally implemented by the USA which has now been shared with 56 countries globally (Cock et al. 2009). *Anagyrus lopezi* (De Santis) (Hymenoptera: Encyrtidae) sourced from Brazil, Paraguay and Bolivia to control cassava mealybug, *Phenacoccus manihoti* Matile-Ferrero (Hemiptera: Pseudococcidae), financed by a consortium led by the International Institute of Tropical Agriculture, has been shared with 31 countries in Africa (CABI 2022). *Neochetina eichhorniae* Warner (Coleoptera: Curculionidae) sourced from Argentina by the USA to control water hyacinth, *Pontederia crassipes* (Martius) (Pontederiaceae), has been shared with 35 countries in Asia and Africa (Cock et al. 2009). *Teleonemia scrupulosa* Stål (Hemiptera: Tingidae) sourced from Mexico by Australia to control Lantana weed, *Lantana camara* L. (Verbenaceae), has been shared with 39 countries (Cock et al. 2009).

Exploration for new biological control agents typically leads to improved understanding of biodiversity in source countries. For example, exploration for biological control agents of weeds in Europe has shown that often there are 100–200 species associated with the target (Cock et al. 2009). Biological control research also leads to greater understanding of the ecology of the target pest or weed useful for better targeting an integrated management approach (Sheppard 2000; Orr 2009).

The free use and exchange of biological control agents also supports multiple United Nations sustainable development goals (SDGs) (Cock et al. 2009; Dangles and Casas 2018; Wyckhuys et al. 2020; Mason et al. 2021). For example, the introduction of the parasitoid *Anagyrus lopezi* led to suppression of cassava mealybug, demonstrating how biological control contributed to poverty alleviation (SDG 1), food security including zero hunger (SDG 2), good health and well-being (SDG 3), quality education (SDG 4), clean water and sanitation (SDG 6), decent work and economic growth (SDG 8), industry innovation and infrastructure (SDG 9), sustainable cities and communities (SDG 11), life on land (SDG 15), peace justice and strong institutions (SDG 16), and partnership for the goals (SDG 17) (Dangles and Casas 2018).

The path forward

It is clear that implementation of ABS measures has and will continue to present challenges for biological control. Classical biological control will be particularly impacted by increased processes and the associated costs, resulting in delay agent releases. In recognition of the importance of classical biological control to global plant, ecosystem and human health (One Health initiative, WHO 2022), the IOBC Commission on Access and Benefit Sharing suggests that classical biological control be considered as a non-commercial public good activity that provides benefits for the global community. We recommend in order of priority that those developing ABS legislation and measures consider: (1) simplified, straightforward ABS procedures specific for accessing biological control species for classical biological control as mandated by article 8.a of the NP, and (2) a multilateral agreement on use and exchange of classical biological control agents (see Mason et al. 2023b).

Conclusions

There is a need to increase awareness of the NP and ABS among the broader biological control community. A better understanding of how implementation of ABS regulations and measures impacts access to, and use of biological control genetic resources will enable researchers and practitioners to influence the positions of national governments to consider the positive contribution of biological control to the global community.

There is a need to provide guidance to countries developing ABS regulations to ensure that the special status of biological control is considered, especially in countries that do not have adequate capacity to develop and implement regulations. Simplified measures to

access and use biological control species will enable efficient response to problem species that threaten resources important to human interests. There is a need to propose standard agreements that will enable broader access and use of biological control agents. Multilateral agreements that encourage sharing of effective biological control agents will ensure benefits are provided to all communities. These may also serve as models for countries developing ABS regulations.

There is a need to further develop best practices to demonstrate due diligence by the biological control community. To complement the best practices for invertebrate biological control agents (Mason et al. 2018), best practices for use and exchange of microbial biological control agents has been prepared (Mason et al. 2023a). Additionally, a compilation or ideally a database, where due diligence and/or compliance with national regulations is documented for each biological control agent developed after 2014 could be helpful and increase trust. Guidance for researchers and practitioners considering biological control solutions for new targets on how to access and use genetic resources is provided by Cock et al. (2009) and Mason et al. (2018) and will enhance the reputation of biological control.

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