Shipping augmentative biocontrol agents

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Summary

The majority of worldwide trading in live arthropods is done by specialized companies that produce and distribute beneficial insects, mites and nematodes for augmentative biological control of pests on crops. These beneficial arthropods, predators or parasitoids of crop pests and some nuisance species, that are harmless to humans, plants and other animals, are mass-reared, transported and released in the target environment as a viable alternative to chemical pesticides. As such, they play a major role in achieving a more sustainable and regenerative agriculture. Thousands of international air shipments are performed yearly by up to 30 major companies. Over the decades that this industry has been active, no significant transport problems have arisen. This is due to stringent standards that the industry has generated, including designated departments to deal with quality control and logistics, as well as guides for each species concerning packaging, storage, and transport conditions. In addition, transporters always adhere to the regulatory standards of the importing and exporting countries, which is attested by the documents included by the companies with each shipment. Two major issues arise when shipping live arthropods: firstly, the need to maintain stable environmental conditions within the shipping units (maintaining a cool chain) and secondly to minimize transport time (prevent delays). This paper

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discusses the procedures implemented by the companies to assure quality, the documents required and provided currently, and the challenges to the safe transportation of beneficial organisms.

Keywords

Beneficial arthropods – Biological control – Packaging – Parasitoids – Predators – Transport.

Introduction

The majority of worldwide shipments of arthropods is done by specialized companies that produce and distribute beneficial insects, mites and nematodes for augmentative biological control of pests on agricultural crops. For decades, thousands of shipments of these beneficials have been made every year, without major incidents. This is due to the existence of a highly professional industry, mainly composed of small and medium-sized enterprises, that have established qualified research and development departments, which continuously perform extensive studies to develop optimal transport and storage conditions for the different beneficial species. These arthropods are intended to be released mainly in agricultural crops (often in greenhouses) to safeguard the crops from pest damage (1). In this article we discuss the relevance of augmentative biocontrol; the current status of how these arthropods are transported and traded; the potential risks/problems related with transport; and the future challenges. Only issues concerning the transport itself are discussed, since the import/export and release permits for biocontrol agents (BCAs) are already covered by regulations at the national level (2) and compliance with the regulations needs to be attested by the documents included with each shipment.

Relevance of augmentative biocontrol

Global food production systems are facing the challenge of satisfying the demands for increased crop productivity while maintaining or increasing their environmental and economic sustainability (3). The use of mass-reared natural enemies, predators and parasitoids of pests, has

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been shown to be an effective and a sustainable alternative to pesticide use from an environmental and economic perspective. Biological control re-establishes and enhances natural pest regulation mechanisms as they occur in natural ecosystems. As such, biological control is a main contributor to sustainable agriculture, and it is a key element to achieving the ambitious goals of the European Green Deal (4).

Today, the augmentative release of beneficial arthropods is applied in many areas of agriculture such as fruit and vegetable crops, cereals, maize, cotton, sugarcane, soybean, grapes, and many greenhouse crops (1). It has allowed substantial reduction of chemical pesticide use. A good example is the published analysis of chemical pesticide residues on Spanish peppers upon import to Germany, both before and after the widespread implementation of augmentative biocontrol in 2006/2007 (5). The excessive use of chemical pesticides and the resulting high levels of residues had caused a collapse in the export of peppers by 40% between 2004 to 2007. Following the implementation of augmentative biocontrol, a full recovery was achieved and since 2012 exports increased by 200% (Personal communication, 2021). Nowadays, augmentative biocontrol is the main crop protection strategy in protected vegetable production, especially in Europe and North America (1).

Market for the biological control agents

Since the 1960s, biological control through the augmentative release of predators or parasites grew from a scientific activity to a reliable way of crop protection and a commercially viable alternative to pesticides. Years of fundamental and applied research, together with considerable investments by the private sector, have made this success story a reality. Today, there are about 500 commercial producers of BCAs worldwide (1).

More than 170 species of invertebrate natural enemies are used in augmentative biological control in Europe (6); the number increases to about 219 arthropod species when considering the worldwide scenario (7). Of these, about 32 species are widely used in crop protection (2).

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In 2015 the International Biocontrol Manufacturers Association (IBMA) estimated that between 2013 to 2015 there had been a global increase of around 10-20% in the total sales of biocontrol agents, with the market value of the natural enemies increasing to about EUR 155 million. Europe has the greatest market share of natural enemies, with more than EUR 100 million in sales in 2015, with further sales of about EUR 35 million in NAFTA (USA, Canada and Mexico), and another EUR 20 million in other markets (8, personal communication 2016).

Potential risks of trade in beneficial insects, mites and nematodes for biocontrol

Beneficial insects, mites and nematodes for augmentative biocontrol have been transported in increasing numbers for more than 50 years. Thousands of units (boxes, tubes…) are shipped by air every year while major incidents have never been reported (International Air Transport Association, personal communication, 2021). Moreover, these natural enemies of pests are considered to be safe/harmless for humans in normal use. For this reason, there are no specific protective measures required for their handling (9). They are routinely handled by operators in the production facilities where they are mass-reared, as well as by growers and farm workers in the crops where they are released, without any associated problems.

The only minor exception would be the rare and usually limited problems described with the use of mites (10, 11), due to allergic reactions that can occasionally happen in a small percentage of people that are sensitive to dust mites. These are not different to other allergies produced by foods or fibres (for instance people allergic to certain fabrics). Most, if not all of these cases, happen only when sensitive people are exposed during prolonged time in conditions where the mites are active. For instance, cases have occurred after many days of handling mites directly while distributing them in the crop (12). For most of these cases a simple dust-preventive mask and gloves suffice as protection. However, any allergic situation is very improbable during transport due to the packaging standards (see detailed procedures below).

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There are very low environmental risks associated with these beneficials during transport because the packaging standards minimizes the possibility of accidental releases during transport. More importantly, any environmental risk associated with end use is already covered by regulations of the importing and exporting countries, as these beneficials are authorized to be released in the crops by the national authorities both at the shipping country and at destination. Conformity with these regulations is demonstrated by the permits and documents included with each shipment.

Many commercial BCAs are endemic in the markets in which they are sold, so occur naturally in the environment. Exotic species are subject to extensive risk assessment, carried out with international participation, before import permits are provided (13). A joint EPPO/IOBC Panel on Biological Control Agents continues to evaluate potential environmental risks of exotic BCAs. Several international and regional organizations have produced documents, guidelines and codes of conduct relevant to the importation and release of BCAs. These include the publication of the FAO Code of Conduct for import and release of exotic biological control agents in 1995, and as an International Standard for Phytosanitary Measures (ISPM) in 1996, which was the turning-point for the activities related to the import and release of biological control agents in Europe. The revised version of this ISPM has extended its range from classical biological control to inundative biological control, native natural enemies, microorganisms, and other beneficial organisms, and also includes evaluation of environmental impacts (14).

Another initiative to develop a harmonized regulatory system for their country members was set up by the Organization for Economic Co-operation and Development (OECD) (15). More recently, during its presidency of the European Union (EU) Council in 2021, the Portuguese Government launched a discussion on the potential benefits of greater harmonisation of approaches with regards to use and release of invertebrate BCAs in the EU. This led to Council Decision EU 2021/1102 of 28 June 2021, to request the Commission to submit a study on the situation regarding introduction, production, evaluation,

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marketing and use of invertebrate BCAs within the territory of the Union.

Trading centralised by a professional industry

While hundreds of companies sell beneficial insects, mites and nematodes, fewer than 30 trade internationally. The complex logistical and regulatory requirements for shipping the beneficial insects and mites deter smaller producers from long distance transport. Nevertheless, the bulk of the production of BCAs for augmentative release takes place in a centralized way. There are several reasons for this (2):

- The high standards required, including efficient and reliable production, and quality control systems for BCAs are expensive to develop and maintain. Therefore, it is more economical to manage fewer larger production sites, compared to many small ones.

- The demand for certain products in one single country or region can fluctuate enormously and unpredictably from week to week, depending on crop calendars, pest pressure, climate conditions, etc. This makes forecasting of sales very difficult. Combined with the fact that production scale-up requires time (often months, depending on the life cycle of the species), and the fact that these living organisms have very limited shelf-life, makes it impossible to accommodate the unpredictable variations in local market demand. It would take enormous overproduction (and waste) in each local production site to guarantee sufficient product and product quality throughout the season. Combining production for more regions or countries, stabilizes overall demand and significantly reduces cost of biocontrol for the farmers.

- Centralised production allows the offering of a bigger portfolio, providing versatile choice to customers worldwide to design the best possible biological control programme for their particular requirements.

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Quality assurances

Since the fragile mites and insects can be easily affected by environmental conditions during packaging, storage and transport, thereby compromising their performance in the field, major companies have defined and implemented standard operational procedures (SOPs) to guarantee their quality (16). Two major aspects are 1) the need to ensure that a cool chain is maintained during transport, to avoid mortality and/or quality loss, and 2) the arrival within a few days using the fastest possible route and avoiding delays. The range of optimal temperatures is species dependent. Insulating packaging, icepacks and refrigeration during transport are ways to maintain temperatures and avoid detrimental heat build-up during relatively warm ambient conditions. Preventing loss of quality in colder ambient conditions is more complicated. The biggest challenge occurs when both cold and warm ambient conditions occur during the same shipment. Drastic changes of ambient temperatures can also cause severe problems such as condensation and clumping of material. Companies, as well as subsidiaries/distributors, use climate-controlled rooms, not only during, but also before and after transport. Rooms with intermediate temperatures are often used to cool or warm the products more gradually.

Relative humidity (RH) is a further key parameter, and each species is packaged within different substrates with specific RH, which needs to be adjusted according to the distance of the destination and means of transport.

For some products, carbon dioxide (CO_2) is a third parameter that needs consideration in transport. The concentration of carbon dioxide, often correlated with the level of oxygen availability inside insulating boxes or in the transport vehicle, can reach levels harmful to the living beneficials, leading to reduced vitality of the populations or even mortality.

Monitoring of the temperatures in the insulating boxes and/or in the transport vehicle is generally performed with Data Loggers (Fig. 1), and

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for some products loggers measuring RH and/or CO_2 are included as well.

The SOPs typically comprise at minimum quality control (QC) measurements for three stages:

1. after production and before formulation and packaging
2. QC of the packaged products before shipment
3. at the subsidiary/distributor facilities after transport.

QC guidelines for natural enemies compare their quality relative to long-term production standards as well as to wild populations of the same species (16). These guidelines are a result of an intensive cooperation between researchers and the BCA industry. Often the defined threshold values of the examined parameters by the producers (numbers per container, morphological and/or molecular identification, fecundity, etc.) need to exceed the minimum requirements described by the IOBC (16).

Packaging

Beneficial insects, mites and nematodes are packed in multiple layer packaging with well-closed inner containers or sachets. According to the species, different containers are used: plastic or cardboard bottles or tubes sealed with a ventilated cap, bulk bags (paper or plastic) and blisters. Some species of predatory mites are packaged in individual sachets, which are made with a breathable paper or a compostable foil. For transport, all these containers are placed inside polystyrene boxes, together with ice packs (frozen at least 24 h in advance), as well as low weight insolation and buffer materials (see Figure 1 as an example). The boxes are completely sealed, and sometimes additionally placed inside a cardboard container. For certain species of mites, small openings are included for ventilation (Fig. 1). The size and thickness of the polystyrene box, the number of product units, number and type of icepacks and buffer packs is adjusted according to the species, destination and means of transport.

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All the products are labelled with unique codes for traceability to the batch of production and packaging, as well as with the name of the species, quantity of individuals, adequate range of temperatures for storage, pictograms advising how to handle and release the material, etc. The specific information provided on the label is often regulated by national authorities, and so may differ by destination.

[Place the Figure 1 here]

Current transport situation and challenges

Shipments of beneficial insects, mites and nematodes for biocontrol are conducted in accordance with the regulations of both the exporting and importing countries. This always includes an invoice, packing list and Air Waybill, and usually also a veterinary and/or phytosanitary certificate. The exact certificates required is determined by the receiving country. Beneficial insects, mites and nematodes do not necessarily fit under the categories of animals or plants, for which these certificates have been developed. As a result, often information is requested that is not relevant/applicable for the invertebrates shipped, reflecting either a pragmatic extension of an existing requirement or a lack of knowledge about these beneficials. An example is that some importing European and Asian countries request sanitary certification in the form of a declaration from the exporting veterinary authorities that the populations to be shipped are free of a list of pests and diseases, most of which are specific for bees and irrelevant for other arthropods.

A major problem for the sector is the high price for air shipment of beneficials, which often is much higher than for shipments of other materials. An additional challenge is finding courier companies, since most of them implement blanket rejections of all living animals in their transport rules; they do not differentiate between transporting tigers and beneficial arthropods (17, 18). For instance, only the courier company MRW™ is accepting the transport of living animals from Spain. For international shipments, specific transport service agreements have been developed between some of the major BCA companies, producing high volumes of the beneficial arthropods for augmentative biological control, and specific courier companies in order to get exemptions from

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the general live animal exclusion for the transport. Here, a more differentiated assessment of risks associated with transporting different living organisms would be welcome.

A positive example of constructive collaboration includes the discussions between IATA and IBMA in updating the Live Animal Regulation (LAR) (9). Currently, the LAR of IATA includes Container Requirements for beneficials, insects, bees and bumblebees (CR 61-68). This provides instructions and background information for exporters on how to pack some different types of insects and mites as well as for airline and ground staff on how to handle insects and mites in transport. As of 2022, separate Container Requirements are provided for beneficial insects, mites and nematodes (9). These Container Requirements can also be used by courier companies.

An additional problem that has been affecting transport in general, and the shipping of BCAs in particular, is the restrictions imposed by the COVID-19 pandemic. Limitation in flight availability has strongly compromised the transport of BCAs. However, the pandemic has highlighted more than ever the correlation between human health, environmental protection, and economics, as well as the need to create/maintain good local agricultural production. It is in this framework that biological control plays a critical role by enabling a more regenerative agriculture.

Conclusions

Transport of BCAs from centralized production points is essential to the success of agricultural pest management across markets in many different countries. By assuring the right transport conditions and minimizing transport time, the transport sector has a vital role to play in contributing to the efficient production of safe and healthy food for the growing world population. Grower motivation, legal requirements, and social demands in favour of food and ornamental plants produced with less or no pesticide residues will stimulate an increase in the worldwide trade of beneficial insects, mites and nematodes, used in augmentative biological control.

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Despite the often-limited knowledge about these beneficial arthropods by the transport services, which may generate problems, many transport organisations have worked with the major biocontrol companies to safely arrange thousands of shipments internationally. However, rejection of shipments of beneficial mites and insects by courier companies under blanket bans on transporting live animals could compromise this success story. A better understanding of the contribution of these arthropods to the production of safe and healthy food, and their general innocuousness, would be desirable. For this purpose, any possible guidance for regulatory authorities would be welcome, as long as it is fit for purpose and does not generate irrelevant hurdles which could compromise the required transport and trading of these beneficials.

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References

1. van Lenteren J.C., Bolckmans K., Köhl J., Ravensberg W.J. & Urbaneja A. (2018). − Biological control using invertebrates and microorganisms: plenty of new opportunities. *Biol. Control*., **63**, 39–59. doi:10.1007/s10526-017-9801-4.

2. Riudavets J., Moerman E. & Vila E. (2020). − Implementation of integrated pest and disease management in greenhouses: from research to the consumer. *In* Integrated Pest and Disease Management in Greenhouse Crops (M. Gullino, R. Albajes & P. Nicot, eds). Plant Pathology in the 21st Century 9, Springer Nature, Switzerland, 457–485. doi:10.1007/978-3-030-22304-5_16.

3. Godfray H.C.J., Beddington J.R., Crute I.R., Haddad L., Lawrence D., Muir J.F., Pretty J., Robinson S., Thomas S.M. & Toulmin C. (2010). − Food security: the challenge of feeding 9 billion people. *Science,* **327,** 812–818. doi:10.1126/science.1185383.

Pre-print

4. Hulot J.F. & Hiller N. (2021). − Exploring the benefits of biocontrol for sustainable agriculture – a literature review on biocontrol in light of the European Green Deal. Institute for European Environmental Policy. Available at: https://ieep.eu/uploads/articles/attachments/dd5ba87b-172b-44d2-ac39-782b17589b88/IEEP%20-%20Exploring%20the%20benefits%20of%20biocontrol%20for%20sustainable%20agriculture%20(2021).pdf?v=63791680901 (accessed on 28 October 2021).

5. Chemisches und Veterinäruntersuchungsamt (CVUA) − Pesticide residue monitoring program shows impact: noticeably Fewer Residues in Spanish Sweet Peppers! Chemisches und Veterinäruntersuchungsamt Stuttgart, Germany. Available at: http://cvuas.untersuchungsämter-bw.de/pdf/druck_pest_paprika5_EN.pdf (accessed on 28 October 2021).

6. Cock M.J.W., van Lenteren J.C., Brodeur J., Barratt B.I.P., Bigler F., Bolckmans K., Cônsoli F.L., Haas F., Mason P.G. & Parra J.P. (2010). − Do new access and benefit sharing procedures under the Convention on Biological Diversity threaten the future of biological control? *Biol. Control*., **55**, 199–218. Supplementary material on online version (case studies, natural enemy releases, country views concerning ABS). doi:10.1007/s10526-009-9234-9.

7. van Lenteren J.C. (2012). − The state of commercial augmentative biological control: plenty of natural enemies, but frustrating lack of uptake. *Biol. Control*., **57**, 1–20. doi:10.1007/s10526-011-9395-1.

8. Dunham W.C. (2015). − Evolution and future of biocontrol. *In* 10th Annual Biocontrol Industry Meeting (ABIM), 20 October 2015, Basel, Switzerland, 23 pp. Available at: www.abim.ch/index.php?eID=tx_nawsecuredl&u=0&g=0&t=1489234639&hash=9a70d39f93f7e559c74c63844ae047a9aa3c37ea&file=fileadmin/abim/documents/presentations2015/Keynote_Dunham_ABIM_2015.pdf (accessed on 24 January 2022).

Pre-print

9. International Air Transport Association (IATA) (2021). − Live Animals Regulations (LAR): 2022 (48th ed.). IATA, Montreal, Canada. 543 pp.

10. Danish Ministry of Environment (2007). − Health effects of predatory beneficial mites and wasps in greenhouses. The Danish Environmental Protection Agency, Pesticides Research No. 110 2007 129 pp. Available at: www2.mst.dk/udgiv/publications/2007/978-87-7052-513-8/pdf/978-87-7052-514-5.pdf (accessed on 24 January 2022).

11. Suojalehto I., Hölttä P., Suomela S., Savinko T., Lindström I. & Suuronen K. (2021). − High prevalence of sensitization to mites and insects in greenhouses using biologic pest control. *J. Allergy. Clin. Immunol Pract.*, **9** (11), 4130–4137. doi:10.1016/j.jaip.2021.07.014.

12. Skousgaard S., Thisling T., Bindslev-Jensen C. & Baelum J. (2010). − Occupational asthma caused by the predatory beneficial mites *Amblyseius californicus* and *Amblyseius cucumeris*. *Occup. Environ. Med.,* **67** (4), 287–287. doi:10.1136/oem.2009.049403.

13. Bigler F., Babendreier D. & Kuhlmann U. (eds) (2006). − Environmental Impact of Invertebrates for Biological Control of Arthropods: Methods and Risk Assesment. CABI Publishing, Wallingford, UK. doi:10.1079/9780851990583.0000.

14. Food and Agriculture Organization of the United Nations (FAO). (2017). − International standards for phytosanitary measures (ISPM) 3: Guidelines for the export, shipment, import and release of biological control agents and other beneficial organisms. Rome, Italy. Latest version of all International Standards for Phytosanitary Measures will appear here: www.ippc.int/en/core-activities/standards-setting/ispms/

15. Organisation for Economic Co-operation and Development (OECD) (2004). − Guidance for information requirements for regulations of invertebrates as biological control agents (IBCAs). OECD Environment, Health and Safety Publications. Series on Pesticides 21, Paris, France, 22 pp. Available at:

Pre-print

www.oecd.org/env/ehs/pesticides-biocides/28725175.pdf (accessed on 24 January 2022).

16. van Lenteren J.C., Hale A., Klapwijk J.N., van Schelt J. & Steinberg S. (2003). − Guidelines for quality control of commercially produced natural enemies. *In* Quality control and production of biological control agents: theory and testing procedures (J.C. van Lenteren J.C., ed.). CAB International, Wallingford, UK, 265–303. doi:10.1079/9780851996882.0265.

17. SEUR (2020). – Prohibited goods. Available at: www.seur.com/en/private/send/prepare-your-package-for-shipping/prohibited-goods/ (accessed on 24 January 2022).

18. FedEx (2022). – Global Prohibited and Restricted Items. Available at: https://crossborder.fedex.com/us/assets/prohibited-restricted/ (accessed on 24 January 2022).

Pre-print

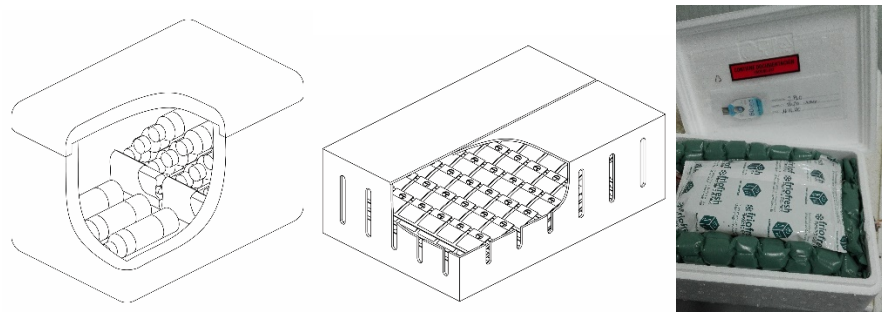

Fig. 1

Drawings showing the preparation of shipments of BCAs, comprising (a) sachets of mites inside a cardboard cage, and (b) several plastic bottles surrounded by buffer materials and ice packs, placed inside a polystyrene box. A picture (c) displaying the detail of the Data-logger placed on the lid is also showed

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