Marie Skłodowska Curie Innovative Training Network on Breeding Invertebrates for the Next Generation Biocontrol: BINGO

Increased demand for agricultural goods to feed a fast-growing world population is challenging not only production systems but crop protection practices as well. Invertebrate pests cause yearly worldwide losses of around €73 billion in annual crops and stored products, representing a huge threat to food security. Moreover, movement of exotic pests to new areas due to trade activities and climate change is placing further demands on crop protection. At the same time, crop protection practices are increasingly constrained. This holds for chemical control because of reduced maximum residue limits and the banning of certain pesticides, as well as for biological control using imported invertebrates because of stricter regulation and more difficulty accessing exotic species (see 'Biological control and arthropod invasions, this issue). Thus while the use of invertebrates for biological control has been advocated as a more sustainable approach to control agricultural pests, reliance on exotic natural enemies to control introduced exotic pests may not be a viable approach. This means governments need to find and develop solutions to reduce the dependence on non-native natural enemies for biological control in order to promote more secure and sustainable food production systems.

One promising alternative to reduce or even eliminate the need to import new exotic natural enemies is to optimize established exotic and native biocontrol agents. This is a realistic technical goal, achievable through the exploration of natural genetic variation and selective breeding. It requires professionals with the interdisciplinary skills to bridge the gap between fundamental sciences, such as genomics and genetics, and applied sciences, such as the practice of biological control. Currently, however, there is a lack of such scientists. It was in this context that the expertise of academia, industry and agricultural organizations was drawn on in a collaboration that gave rise to the BINGO project.

The consortium BINGO was created as an International Training Network for early stage researchers and is funded by the Marie Skłodowska Curie scheme of the EU Horizon 2020 programme. BINGO brings together participants from prominent universities, institutes and industry in nine European countries and advisory board members from outside the EU. The network consists of 24 researchers and 13 PhD students, who will carry out their projects at the BINGO partners' facilities. This initiative aims to (i) improve current biocontrol practices through the exploration and exploitation of natural genetic variation present in native natural enemies, (ii) extend the application of quantitative and population genetics to the invertebrate biocontrol field, and (iii) train 13 young researchers in an interdisciplinary environment. BINGO will provide the PhD students with education at established universities as well as access to the state-of-the-art techniques and equipment available at the different participating institutions. Moreover, the young researchers will benefit in terms of career enrichment and networking opportunities from an extensive internship programme of exchanges between BINGO partners. BINGO is not only multidisciplinary by nature, encompassing disciplines from molecular genetics and genomics, to behaviour and physiology, and ecology and evolution, but will also implement new technologies that are likely to improve the efficiency of biological control.

As there are several areas of interest when it comes to selective breeding, BINGO is divided into different Work Packages (WP) in order to target all the steps of biocontrol practice from production, to field performance and risk assessment.

Production of natural enemies is a crucial step for the quality and subsequent performance of these invertebrates in the field. Improvements in production are likely to decrease costs related to handling procedures thus making biocontrol agents more accessible for growers. A WP leading research on rearing and storage focuses on aspects of mass rearing, allergy (to moth scales), sex ratio, clutch size and exploitation of symbiotic bacteria for increased production. The objectives of this WP will be addressed through three research projects: (1) Mutation genetics in the flour moth *Ephestia kuehniella*; (2) Clutch size, sex ratio and differential mortality in the *Bracon hebetor/B. brevicornis* species complex; and (3) Optimization of mass rearing of *Bactrocera oleae* and its parasitoids.

A major concern after the release of natural enemies is their impact on local ecosystems, and this is a specific issue underlying the creation of BINGO. Concerns will be addressed by a WP on risk assessment, which will coordinate monitoring and risk assessment aspects through two research projects: (1) Benefits and risks of using the native polyphagous biological control agent, *Anastatus bifasciatus*, against invasive stink bug *Halyomorpha halys*; and (2) Monitoring pre- and post-release diversity in local parasitoid populations.

In terms of performance of biocontrol agents, the different trophic levels at which pest species and biocontrol agents interact will determine the success of pest suppression. A WP focusing on performance will try to identify and predict the key traits related to field performance through mathematical modelling and will attempt to improve these traits using quantitative genetic approaches in three biocontrol agents. The projects in this WP are: (1) Improving pest control efficiency: a modelling approach; (2) Promoting adaptability of *Amblyseius swirskii* predatory mites to tomato crop; (3) Minimizing plant damage through selected *Nesidiocoris tenuis*; and (4) Expanding the range of uses of *Phytoseiulus persimilis*. Success of artificial selection on performance traits of these species will be tested in laboratory, semi-field and field conditions.

The major genomic aspects of BINGO are coordinated in a WP on genomic variations, whose objectives are to (i) develop genome-wide genetic markers for field monitoring, estimating and tracking variation of mass-reared biocontrol agent strains, (ii) unravel the genes underlying phenotypic variation in relevant biocontrol agent traits, and (iii) develop genomic selection methods for improvement of biocontrol agents. These objectives will be targeted through four research projects: (1) Population genomics of natural enemies; (2) Genomic basis of life history traits and reproductive potential; (3) Identification and characterization of naturally occurring variation affecting reproductive diapause; and (4) Genome-based selection for the improvement of natural enemies in biocontrol.

BINGO was officially launched in January 2015 and the first PhD students started their projects six months later. As part of their training the young researchers will attend annual summer schools and they will also participate in local and international scientific conferences to present the main results as their research progresses. Network meetings will be held annually to discuss experimental approaches and present progress and discoveries. The first workshop took place on January 2016 in Valencia, Spain, with approximately 100 participants. Outreach is also an important aspect of the project and those activities will be coordinated locally by each partner in their communities in order to transfer knowledge to professional groups, high school students and the public in general. Moreover, results of the research projects will be disseminated through publication in scientific journals.

For further information about BINGO, the projects, researchers and PhD students, or to subscribe to the BINGO newsletter, visit the website: www.bingo-itn.eu/.

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Protecting Elm Trees

Dutch elm disease, *Ophiostoma ulmi*, killed elm trees (*Ulmus* spp.) across Europe and the USA in the 1920s–30s, with a worse epidemic caused by *O. novo-ulmi* decimating trees from the 1970s. The disease is vectored by bark beetles and also transmitted via interconnecting root systems. Landscapes were left denuded of elms and recovery has been slow. Tree varieties with a high level of resistance to the disease are now available which gives hope for the future. However, mature trees may be very valued, notably in urban settings. The preventative fungus-based product Dutch Trig® (BTL Bomendienst, Apeldoorn), developed by the University of Amsterdam, has been used commercially to protect valuable trees from infection in the Netherlands since 1992, and more recently in other countries. This programme is reviewed in an open-access paper in *BioControl*.[1] The active ingredient, *Verticillium albo-atrum* strain WCS850, is injected as an aqueous conidiospore suspension into the tree's vascular system. It induces disease resistance in healthy elms and protects them from infection via bark beetles although it does not control the disease in infected trees, nor prevent transmission from infected trees via root systems. Since 2010, only 0.1% of treated trees in the Netherlands have become infected via beetles, and 0.4% via root transmission. Infection through beetle transmission in treated trees has decreased significantly since Dutch Trig® was introduced. Up to 30,000 trees are treated at a cost of around €16–25 per tree in the Netherlands each year. Annual treatment is necessary, so it is used mainly for mature trees in settings where their amenity value is high, and replacement would be less desirable and more expensive than treatment. The product is now also registered in the USA, Germany, Canada and Sweden and registration is in progress in the UK. In 2015, it was used to treat over 28,000 valuable, at-risk trees in the five countries where it is registered. One limitation is that survival of the live conidiospores (and therefore product life) is short and there is interest in developing a product with greater shelf-life. Even without that, Dutch Trig® is seen as a valuable component of integrated disease management alongside sanitation and replanting with resistant varieties.

[1] Postma, J. and Gossen-van de Geijn, H. (2016) Twenty-four years of Dutch Trig® application to control Dutch elm disease. *BioControl*. DOI:10.1007/s10526-016-9731-6.

A Gel for Entomopathogenic Nematodes

One problem in developing effective formulations for above-ground application of entomopathogenic nematodes (EPNs) is that, because they are adapted to subterranean environments, they are prone to damage by UV light and desiccation. A study reported in *Biocontrol Science and Technology* assessed whether the efficacy and persistence of above-ground applications of *Steinernema carpocapsae* were enhanced by combining the EPNs with protective gel and anti-UV ingredients (titanium dioxide and octyl methoxycinnamate).[1] The authors found that the gel led to significantly greater target pest mortality outdoors, while greater EPN longevity was recorded in a glasshouse environment, with titanium dioxide increasing the gel's protective properties. They conclude that titanium dioxide in a low concentration formulation of the protective gel makes the product more viable for growers to use.

[1] Dito, D.F., Shapiro-Ilan, D.I., Dunlap, C.A., Behle, R.W. and Lewis, E.E. (2016) Enhanced biological control potential of the entomopathogenic nematode, *Steinernema carpocapsae*, applied with a protective gel formulation. *Biocontrol Science and Technology* 26, 835–848.