9.1 From Molecule to Landscape - Integrating Molecular Biology and Landscape Ecology to Open New Opportunities for Biological Control in East Asia

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At the time of the 2017 ISBCA, biological control has never been at a more exciting stage of development, and the need for biological control has never been greater. This paper will explore how the recent advances in two particular fields open great opportunities to both understand fundamental aspects of biology that underpin our discipline as well as to deliver more effective solutions to end-users. First, the rapidly falling cost of DNA sequencing and capacity for bioinformatics analyses mean that genomic data-rich studies of agents and functionally related species are increasingly feasible and powerful. Second, theoretical advances in spatial ecology are complemented by unmanned aerial vehicles (UAVs or ‘drones’) as platforms for advanced remote, hyperspectral imaging. These high-tech approaches will allow biological control to more consistently achieve end-user benefits such as in recent work in Asian rice (Gurr *et al.*, 2016).

Traditionally, biological control research effort has been at the level of whole organisms, the agents and their targets. A crude illustration of this is that a search of Web of Science for ladybird AND biological control returns more than 1400 articles dating back over a century to work in Arizona (Morrill, 1913). In more recent decades, biological control researchers have explored how manipulation of the environment, usually at the field scale, can promote natural enemy activity. This is reflected by a search of Web of Science using habitat manipulation AND biological control which finds 137 papers dating back less than 40 years to the work by Altieri and Whitcomb (1979). Work at the larger spatial scale dates back over a similar period. Web of Science records for landscape AND biological control number 1500 and range back to the early 1970s (Brewer, 1972). Perhaps surprisingly, a search for molecular AND biological control finds over 2500 papers dating back to the early 1930s including work on chemical stimulation of parasitoid ovipositors (Dethier, 1947). Even a search for genomic AND biological control finds well over 1000 papers extending back to 1982 work on baculoviruses (Huang *et al.*, 1982). Accordingly, biological control research has long been attuned to the relevance of the extreme levels of biological organisations (i.e., from molecule to landscape) (Fig. 9.1.1). The exciting prospect now awaiting the field is that technological advances now provide far greater power, accessibility and affordability.

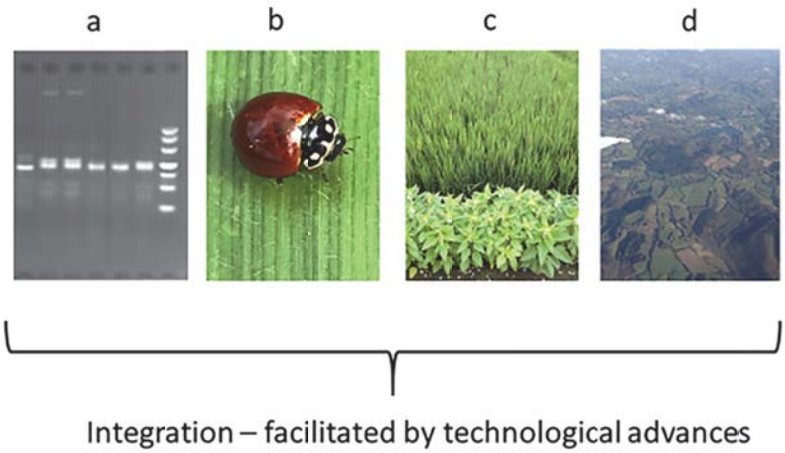

Fig. 9.1.1. Levels of biological organisation relevant to biological control. Traditionally, research effort has been at the level of whole organisms (agents), panel **b**; work in more recent decades has often used local scale habitat manipulation to promote biological control (with sesame nectar plants, for example), panel **c**; or considered the influence of the wider landscape, panel **d**; and at the opposite (molecular) extreme, panel **a**.

At the molecular and genomic level, the rapidly declining cost of analyses, especially sequencing (Metzker, 2010) is providing unprecedented power to understand phenomena such as genetic control of traits and adaptation to environmental conditions in biological control agents and targets. At the other extreme, advances in imaging, remote sensing and – especially – UAVs have been rapid in the last decade. UAVs can be purchased cheaply via the Internet and are already being assessed for surveillance, monitoring and even release of biological control agents (Faithpraise *et al.*, 2015). Hyperspectral imaging systems now offer scope for remote sensing of pests (Nansen, 2016). Combining imaging technologies with UAVs could allow efficiencies in inundative biological control programs by making it fast, cheap and easy to release appropriate numbers of agents in positions within the crop only where control is needed. As the cost of robotic technologies declines, it is likely to be become possible to use UAV-mounted robotic equipment to efficiently sample pests, plants or agents in a spatially explicit manner from the landscape. These could then be processed for various types of analyses – including genomic – to assess factors such as insecticide resistance genes in the pest (indicating a particular need for biological control) and the nutritional status of parasitoids (indicating the need for more nectar plants). Ultimately, genomic analyses could be done on such samples to build comprehensive landscape meta-genomic maps of biological control agents, targets, and the microbes and plants associated with them in the landscape, and thereby optimise control of pests. This capacity will have great utility in allowing global agriculture to meet human needs, but especially so in Asia where high population densities and growth rates make the challenge especially great.

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