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General News

Bringing a New Biofungicide to the Market in Mexico

A case study published in the *Electronic Journal of Biotechnology*[1] describes how a biofungicide for controlling post-harvest anthracnose in mango was developed and launched on the Mexican market. The authors say that they know of no previous publication on an innovation process leading to the commercialization of a biocontrol agent for a phytopathogen, and none for an emerging country such as Mexico. They relate how various actors from different sectors came into the project as new expertise became critical as the project moved from science through large-scale testing to regulatory procedures and finally commercialization. The article also indicates that it was the researchers' determination that this was not going to end up as another 'might have been' story that provided the energy to set and keep the ball rolling, a process backed by industry and government partners and funding via eight grants, primarily from the National Science and Technology Council (Consejo Nacional de Ciencia y Tecnología – CONACYT), the Ministry of Agriculture (Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación – SAGARPA), the Government of the State of Morelos and the research fund of the National University of Mexico (Universidad Nacional Autónoma de México – UNAM).

Mango is an important crop in Mexico and the country is a leading world exporter; some 14% of annual production is exported. However, the fruit export sector suffers considerable losses from phytopathogens, which are present throughout the production chain. The authors explain the challenges facing growers producing fruit for export. Entire consignments may be rejected, which not only inflicts financial losses but can damage relations with clients. Furthermore, in the last decade many importing countries have introduced stringent limits on pesticide residues in food making disease control more difficult. The researchers in this project were seeking a new biologically based control method for *Colletotrichum gloeosporioides*, the causal agent of mango anthracnose.

The authors describe how, at the start of what became a 12-year multi-institutional, multi-disciplinary project, the focus was on the scientific and technological challenges of isolating and screening for promising organisms against the pathogen, and then developing effective formulation and application techniques and conducting first field trials. Isolation of bacteria and yeasts from mango was conducted by the Centro de Investigación en Alimentación y Desarrollo (CIAD), who carried out extensive field sampling in mango orchards in Sinaloa State in western Mexico, the country's main mango-producing region. Approximately 200 isolates of bacteria and yeast were preserved for screening to identify biocontrol candidates. This was achieved by measuring inhibition of mycelial growth of *C. gloeosporioides in vitro*, from which seven bacterial isolates and one yeast isolate were deemed worthy of further investigation.

These results were presented at a meeting supported by the Mexican National Council for Science and Technology in 2000. Here, the CIAD team met with scientists from UNAM's Instituto de Biotecnología (IBt) for the first time, and agreement was reached for collaborative research to confirm the robustness of the initial results and the most promising isolates, to investigate optimal concentrations and application intervals and timing, to conduct semi-commercial- and commercial-scale experiments, and to assess efficacy over different agricultural cycles. This led, among other things, to the candidate biocontrol agents being narrowed down to two bacterial isolates, one each of *Bacillus subtilis* and *Rhodotorula minuta*.

The advantage of not following a strictly scientific publication route is illustrated by the way the scientists made an important contact. An article about the project in *Claridades Agropecuarias*, a non-scientific publication read widely by agribusiness professionals in Mexico, caught the attention of an innovative Mexican fruit exporting company, El Rodeo Fruit, who contacted the team and expressed interest in becoming involved. The company subsequently conducted semi-commercial and commercial field trials with a *B. subtilis* strain 83 solid formulation product, which achieved excellent results: treating with the experimental product led to a crop with 80% export-quality mangoes cf. 27% from a conventional fungicide-based treatment. As importantly, El Rodeo Fruit's involvement grew trust in the product; they made the product available free to growers, who were impressed with the results it achieved and talked about it to other growers. The company also offered a bonus to growers using the product and documenting its use, and these data and the involvement of the producers gave a more commercial aspect to the project. The authors credit this collaboration as critical to the project's continuation and eventual success.

At the end of 2007, though, the project ground to a halt. By then the researchers had demonstrated that *B. subtilis* strain 83 had commercial potential as a biological control agent, a robust pilot-scale production technology for production and formulation of a solid biofungicide based on *B. subtilis* spores was ready to be scaled-up to industrial level, and the market demand for high-quality mangoes could be better met by a biologically based product than conventional treatments – but companies were slow to show interest and more than a year after they started, discussions were going nowhere. However, instead of abandoning the project, the team set out on the long road to do it themselves. The authors make it clear that this is not a process that scientists can negotiate alone, and they document in detail the essential support they had from Mexican institutions.

First they needed to license the technology, which includes an array of complex intellectual property (IP) issues and other legal and financial matters, which really needs the involvement of a specialized technology transfer office. Fortunately IBt has a Technology Transfer Office which deals with IP protection of technology generated by its researchers and its transfer to the private sector. This office facilitated the drafting of an invention description and a patent application was filed in 2006.

While this process was progressing, the forthcoming licensing of the product was promoted within the national agroindustry, but still no potential partner was identified. The stalemate prompted the creation of a UNAM spin-off company Agro&Biotecnia in 2008 (created by IBt researchers and the first of the currently five IBt's spin-off companies to put a product on the Mexican market), with agreement being reached with CIAD on co-ownership of the invention and the responsibility of the IBt Technology Transfer Office for patent management and technology out-licensing. The researchers also brought in a partner with long experience in fermentation, quality control and manufacturing.

The next significant factor was the support available to the fledgling company under the Sistema Nacional de Incubación de Empresas. This system of business incubator organizations has the resources and expertise to guide the development and implementation of a business plan for new entrepreneurs. The development of Agro&Biotecnia's business plan was supported by the Centro Morelense de Innovación y Transferencia Tecnológica (CeMITT), and it was their involvement that led to the biofungicide being named Fungifree AB®, while their relationship with regulatory professionals supported Agro&Biotecnia in registering the product and the trademark with the Mexican authorities.

Regulation in Mexico for microbial pesticides is dealt with jointly by SAGARPA and the National Commission for the Prevention of Sanitary Risks (Comisión Federal para la Protección contra Riesgos Sanitarios – COFEPRIS), a division of the Mexican Ministry of Health. Biological efficacy tests for Fungifree AB® were conducted in mango orchards in southern Sinaloa in the first half of 2009, and a report was submitted to SAGARPA in September 2009, who issued a positive opinion in June 2010. COFEPRIS, which is responsible for assessing health risks from independent evidence (provided by certificated laboratories) of product safety and quality, gave approval in April 2011. The entire process took some three years and cost almost US$40,000 for this one disease on one botanical group.

The remaining aspect the paper deals with is commercialization, and here the authors point to the very beneficial relationship developed at this stage with the agrochemical company FMC Agroquímica de México, which has expertise in marketing and a strategy for building its environment- and farmer-friendly business, with a 'Grow Organic' line. FMC facilitated product positioning and increased brand recognition by using a variety of channels to disseminate information. Finally, 12 years after the project began, Fungifree AB® was launched in November 2012 at the Guanajuato Agro-Exhibition 2012, one of the most important events for the agro-industry in Mexico.

But this is not the end of the story. Further applications are being explored, as there are few effective treatments for anthracnose. Based on trial results supplied by the researchers, SAGARPA has endorsed its biological effectiveness on avocado, papaya and citrus fruits, and registration for use on these crops has been approved very recently (June 2013). In addition, research suggests that Fungifree AB® may have applications for controlling powdery mildew and this is being investigated further.

To end the paper, the authors discuss lessons learned. They underline the point made throughout the paper about the importance of scientists recognizing that actors from different sectors – academic, industrial and service – with divergent backgrounds, capabilities and even language play different but essential roles in the innovation process. They also note that it is important to see the science as just part of the picture and to step back from insisting on a wholly scientific approach. They conclude by saying that this case study proves that commercial development of biopesticides can be achieved in emerging countries such as Mexico, crediting the technical and scientific excellence to be found in Mexican research groups.

[1]Galindo, E., Serrano-Carreón, L., Gutiérrez, C.R., Allende, R., Balderas, K., Patiño, M., Trejo, M., Wong, M.A., Rayo, E., Isauro, D. and Jurado, C. (2013) The challenges of introducing a new biofungicide to the market: a case study. *Electronic Journal of Biotechnology* 16(3), 23 pp. http://dx.doi.org/10.2225/vol16-issue3-fulltext-6

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Biological Control of Palm Weevils: Rediscovering Forgotten Opportunities

Two overlooked natural enemy species may provide new biocontrol options for palm weevils in coastal Colombia, and potentially more widely.

The American palm weevil (APW), *Rhynchophorus palmarum,* is the most important coconut pest in Latin America and the Caribbean. Its pest status is aggravated by its ability to vector the nematode *Bursaphelenchus cocophilus*, the causal agent of red ring disease (RRD), which has killed hundreds of thousands of coconut palms in tropical America and thus affected the livelihoods of thousands of smallholder farmers. In the Old World, a close relative originating in South Asia, the red palm weevil (RPM), *Rhynchophorus ferrugineus*, has a history of invading new areas. Over the last 30 years it has devastated the date palm industry in the Middle East[1], and more recently it has expanded in the Mediterranean threatening the typical, landscape-dominating canary date palm (*Phoenix canariensis*) with extinction. This weevil species has now reached the Americas: it was accidentally introduced in Curação in 2008 from where it spread to Aruba[2], and in 2010 it was detected in California (http://cisr.ucr.edu/red_palm_weevil.html). *Rhynchophorus ferrugineus* is polyphagous, like its American congener, but its direct damage is worse as it usually kills the palms it feeds on.

Interest at CIAT in Colombia (Centro Internacional de Agricultura Tropical) was sparked because the APW/RRD situation is particularly severe at the Colombian Pacific coast where the death of thousands of oil palms due to bud rot has facilitated massive multiplication of APW in the decaying trunks. The resulting increase in APW populations and RRD has led to the area-wide destruction of coconut plantations in entire river systems flowing into the Bay of Tumaco, and along the Guapi and Timbiquí rivers further north. For over 60 years, this phenomenon has repeated itself every 12–15 years and can justifiably be called a recurrent epidemic.

Control methods for palm weevils have changed little over the years: mass trapping of weevils in aggregation pheromone baited traps[3], removal of RRD-diseased palms and replanting are the standard procedures for *R. palmarum* and these methods have been tried at Colombia's Pacific coast. Trapping has been shown to give excellent control of the APW/RRD complex in large-scale plantations. However, the implementation of trapping requires continued effort and regular servicing of the traps[4] which is difficult for smallholders, particularly when they do not live on their land as is the case at the Pacific coast.

Pheromone-based trapping is also the control method of choice for *R. ferrugineus* in plantations[5] but is not suitable in the Mediterranean, where the affected palms are ornamentals and scattered irregularly over the landscape, and in alleys, city squares or private gardens. The situation in the Mediterranean is desperate: all current control methods provide only temporary relief and thus measures have to be implemented indefinitely with huge costs for communities.

Biological control has been looked to repeatedly for a solution and reviews[6,7] have identified a great number of biocontrol agents, notably entomopathogenic nematodes and microorganisms. Some of these have been tried extensively but, like synthetic pesticides, require repeated application and once their effect has expired, the problem returns.

In order to achieve lasting alleviation, new approaches for the control of palm weevils are required. Here we present ongoing efforts to find and exploit biocontrol agents as new mortality factors of palm weevil populations, first for the Colombian Pacific coast but with a view to subsequent use in the American tropics beyond Colombia, and possibly even further afield.

Biocontrol agents recorded in Colombia

Two APW biocontrol agents are recorded in the pest management manual of the Colombian oil palm research centre: a predatory histerid beetle, *Hololepta* sp., and an unidentified tachinid fly, both of which occur at low levels[8]. We consider the histerid of little relevance on the basis of its small size, which indicates it would have little effect on APW larvae. In contrast, the record of the tachinid looked promising, especially as a tachinid, *Billaea rhynchophorae*, is listed as an effective larval and pupal parasitoid of *R. palmarum* in Brazil (see below)[9,10].

In the hope of confirming the presence, abundance and identity of the tachinid, we conducted surveys in both areas where it had been collected previously in Colombia: at the Pacific coast on coconut and in the Llanos Orientales (Eastern Plains), where oil palm plantations were surveyed. We collected the *Hololepta* sp. in our surveys, on both coconut and oil palms, mainly from smaller galleries of another palm-boring weevil, *Metamasius* sp. However, tachinids were not found during either survey.

During the surveys in the Eastern Plains, we collected larvae, pupae and adults of another coleopteran predator – one that we did not find elsewhere – in an abandoned six-year-old oil palm plantation. Many APW puparia were empty and showed clear signs of predation, and inside some APW puparia we found a second beetle pupa with very large, asymmetric mandibles. Specimens of this beetle had previously been collected by Fanny Alvañil of the Colombian Palm Growers' Association, Fedepalma, in Cumaral (Meta) in 1990 and identified as the histerid *Oxysternus maximus* by J.M. Kingsolver of the US Department of Agriculture[11]. The rate of predation in our limited set of data was 46.6% of the puparia or 22.5% on the basis of large larvae and pupae combined. As a follow-up, we conducted surveys in oil palm at the Pacific coast but no *O. maximus* were found and the species was unknown to the palm entomologist, Eduaro Peña.

Overlooked opportunities for biological control of palm weevils

Billaea rhynchophorae is a parasitic fly recorded so far only from a limited area of Bahia State in Brazil. Even though its occurrence was first recorded in the 1990s in two publications[9,10] and its parasitism of APW was reported to be substantial, it has never been studied in detail or been given due consideration in the reviews of biological control options for palm weevils[6,7]. This may be because these reviews have dealt only with RPW and the authors may have assumed *B. rhynchophorae* is irrelevant for this species. However, we believe that the tachinid may become the most important parasitoid species for APW in tropical America, and also for RPW should it arrive on the American continent, and it could have great potential for use elsewhere in the humid tropics. A climate match using Homologue™ [12] shows that many of the palm-growing areas in tropical America have similar climatic conditions to the area of endemicity of *B. rhynchophorae*, so the species could become permanently established.

The way forward

The absence of *B. rhynchophorae* and *O. maximus* at the Colombian Pacific coast offers an opportunity to introduce these species and thus increase the natural mortality of the weevil and hopefully reduce the severity of the APW/RRD problem. No other natural enemies of significance were found at the coast and, therefore, the introduction of both species in order to increase natural mortality of APW is suggested.

A preliminary assessment of the risk associated with introducing these two species can be made, even though the knowledge available on them is limited. In the small area from where it is known, *B. rhynchophorae* has been collected from APW on oil palm (*Elaeis guineensis*) and the fan palm *Attalea funifera*[9,10]. In addition, José Inacio Moura has collected the tachinid from other weevil species associated with palms: *Dynamis borassi*, *Amerhinus ynca* and *Rhinostomus barbirostris*, all weevil pests of cultivated and wild palm species. This suggests that the parasitoid is habitat specific to the crown of palms and stenophagous in its feeding habit.

Oxysternus maximus also has a very close association with palm weevils. It is widely distributed, having been collected in Trinidad, the Guianas, Brazil and as far south as Argentina. In all cases it was collected on palms and recorded as a predator of palm-boring weevils. So we can anticipate that it is also habitat-specific to the crown of palms but probably not very selective within this habitat as far as prey is concerned.

Habitat specificity combined with stenophagy or oligophagy would also suggest that both species should attack weevils so far not recorded as prey: all species of the genus *Rhynchophorus* will probably be attacked by both natural enemies .

While *B. rhynchophorae* can be expected to be an active flyer with a short life cycle and a high reproductive potential, yet limited to areas with relatively high rainfall/humidity and temperatures, *O. maximus* should be more robust, more widely adaptable and probably more polyphagous in its feeding habit.

Potentially, these natural enemies could be useful in other suitable areas with APW/RRD problems in Colombia and other interested countries. Furthermore, their biological traits suggest they could have the potential to contain RPM should it reach continental America, and could also be considered for introduction against it in the Old World. If introductions are made in coastal Colombia, they should be carefully monitored for impact on the target pest and non-target species identified as at risk, and this could form the basis of a risk assessment for introductions elsewhere.

[1]Abraham, V.A., Koya, K.M.A. and Kurian, C. (1989) Integrated management of *Rhynchophorus ferrugineus* in coconut gardens. *Journal of Plantation Crops* 16, 159–162.

[2]Kairo, M.T.K., Roda, A., Mankin, R., Chi, W. de, Damian, T., Franken, F., Heidweiller, K., Johanns, C.Y. and Leon, J. (2010) The red palm weevil, *Rhynchophorus ferrugineus*, a new pest threat in the Caribbean: biology and options for management. *Proceedings of the Caribbean Food Crops Society* 46, 87–96.

[3]Oehlschlager, A.C., Chinchilla, C., Castillo, G. and Gonzalez, L. (2002) Control of red ring disease by mass trapping *Rhynchophorus palmarum* (Coleoptera: Curculionidae). *Florida Entomologist* 85, 507–513.

[4]Oehlschlager, A.C., Zaid, A. and Alhadrami, G.A. (2010) Efficiency and longevity of food baits in palm weevil traps. *Acta Horticulturae* 882, 399–406.

[5]Faleiro, J.R., El-Saad, M.A. and Al-Abbad, A.H. (2011) Pheromone trap density to mass trap *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae/Rhynchophoridae/Dryophthoridae) in date plantations of Saudi Arabia. *International Journal of Tropical Insect Science* 31, 75–77.

[6]Murphy, S.T. and Briscoe, B.R. (1999) The red palm weevil as an alien invasive: biology and the prospects for biological control as a component of IPM. *Biocontrol News and Information* 20, 35N–46N.

[7]Faleiro, J.R. (2006) A review of the issues and management of the red palm weevil *Rhynchophorus ferrugineus* (Coleoptera: Rhynchophoridae) in coconut and date palm during the last one hundred years. *International Journal of Tropical Insect Science* 26, 135–154.

[8]Aldana, R.C., Aldana, J.A. and Moya, O.M. (2011) Manejo del picudo *Rhynchophorus palmarum* L. (Col.: Curculionidae). Cenipalma, Bogotá, Colombia, 51 pp.

[9]Moura, J.I.L., Mariau, D. and Delabie, J.H.C. (1993) Efficacy of *Paratheresia menezesi* Townsend (Diptera: Tachinidae) for natural biological control of *Rhynchophorus palmarum* (L.) (Coleoptera: Curculionidae). *Oléagineux* 48, 219–223.

[10]Moura, J.I., Toma, R., Sgrillo, R.B. and Delabie, J.H.C. (2006) Eficiência do parasitismo natural por *Billaea rhynchophorae* (Blanchard) (Diptera: Tachinidae) para o controle de *Rhynchophorus palmarum* (L.) (Coleoptera: Curculionidae). *Neotropical Entomology* 35, 273–274.

[11]Posada Ochoa, L. Zenner de Polanía, I. and Borrero Fonseca, F. (1990) Notas y noticias entomológicas Septiembre–Octubre 1990. Instituto Colombiano Agropecuário, Tibaitatá, Bogotá, Colombia.

[12]Jones, P.G., Díaz, W. and Cock, J.H. (2005) Homologue™. A computer system for identifying similar environments throughout the tropical world. Centro Internacional de Agricultura Tropical CD-ROM series. CIAT Publication No. 342. CIAT, Cali, Colombia, 100 pp. + CD-ROM.

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Earwigs in the Falkland Islands: Host-specificity Testing Biocontrol Agents

Over the last five years the European earwig, *Forficula auricularia*, has become an unwelcome but common sight in the Port Stanley and Mount Pleasant Airport areas of the Falkland Islands, with a few individuals also discovered on isolated farmsteads. The exact date of introduction is unknown but earwigs are now causing substantial damage to garden and commercial crops (commercial lettuce growing has been abandoned), pose health hazards by hiding in hospital equipment and asthma inhalers, and are a nuisance species in autumn when they retreat into houses and hide in anything from food to toothbrushes. Chemical control is proving problematic because the earwigs are widespread and very mobile. Expenditure on pesticides against them in horticulture is high and environmentally undesirable; household spending is also high and the efficacy of pesticide use and other methods is variable.

At a workshop on the feasibility of biological control of invasive non-native species in Port Stanley in March 2012, local invasive species experts and members of the public agreed that *F. auricularia* was the prime target for classical biological control. Such an initiative would also be supported by the Government of South Georgia as it would lessen the risk of earwigs being introduced to South Georgia.

Forficula auricularia has been the target of classical biological control programmes in the past: two tachinids have been introduced to Canada. *Triarthria setipennis* established in Newfoundland and British Columbia, and studies in Newfoundland indicated a considerable reduction in earwig numbers, which was most probably due to high levels of parasitism in the mid-1970s, although no further evaluation of the parasitoid's impact has been undertaken since then. Limited numbers of a second species, *Ocytata pallipes*, were released as parasitized earwigs and adult flies at one site in Ottawa during the 1990s, but the low numbers released in this pilot study makes establishment unlikely and no monitoring has been done. Both species were also introduced USA (as early as the 1920s) and New Zealand but little is known about the success of these releases.

Little is known about the host specificity of either parasitoid, apart from the fact that the ecological host range of *T. setipennis* includes two other European Forficulidae. The host specificity of both potential control agents needs to be better understood before introductions outside their native range, to the Falklands, can be considered. However, there are no native Dermaptera in the Falklands or South Georgia, so non-target risks of introducing earwig parasitoids to the Falklands are low and from that perspective alone little host-specificity testing will be necessary. Under an agreement with the Environmental Planning Department of the Falkland Island Government, CABI is currently carrying out the necessary testing of potential host species, including crickets which are the closest relatives of earwigs recorded on the islands, in the first phase of a project towards the control of *F. auricularia* in the Falklands.

Chile also has a serious European earwig problem in the southern part of the country, particularly in Punta Arenas, and here the future control of earwigs is also being considered. Whereas the risk that parasitoids released in the Falklands would reach the South American mainland is considered low, any host-range testing in Chile will need to include the testing of both native Dermaptera from Chile itself and also of species from neighbouring Argentina. .

In constructing its host-specificity testing strategy, CABI is following guidelines and procedures for testing of invertebrate biocontrol agents developed in recent years by the Organisation for Economic Co-operation and Development (OECD)[1], the Commission on the Harmonisation of Invertebrate Biological Control Agents (CHIBCA) for the International Organization for Biological Control/West Palaearctic Regional Section (IOBC/WPRS)[2] and subsequent authors (e.g. [3]) who have provided more detailed frameworks and protocols. In addition, CABI will consider whether ecological traits of the proposed biocontrol agents could have adverse impact, specifically whether: (i) a decline in earwig populations would have a deleterious effect on native or other predatory species, (ii) predation on the tachinids would release predatory pressure on other species, and (iii) adult tachinids would impact seed setting of native and invasive plants.

If the introductions were to go ahead, CABI does not anticipate an instant impact. Parasitism rates of the tachinids in Europe are relatively low, so it would take 2–3 years for them to establish and begin to have any effect on populations. At the present time, summer releases in two consecutive years are anticipated. If the earwigs remain restricted to the current two settlements, reduction in populations could be fairly rapid once the biocontrol agents are established and provide long-term alleviation of the problem. However, if local outbreaks were to occur at outlying farms through movement of parasitoid-free earwigs, repeated releases of tachinids, or parasitized earwigs, might be necessary in the future.

[1]OECD (2003) *Guidance for Information Requirements for Regulation of Invertebrates as Biological Control Agents (IBCAs)*. OECD, Paris.

[2]Bigler, F., Bale, J.S., Cock, M.J.W., Dreyer, H., Greatrex, R., Kuhlmann, U., Loomans, A.J.M. and van Lenteren, J.C. (2005) Guidelines for information requirements for import and release of invertebrate biological control agents in European countries. *Biocontrol News and Information* 26, 115N–123N.

[3]van Lenteren, J.C., Bale, J., Bigler, F., Hokkanen, H.M.T. and Loomans, A.J.M. (2006) Assessing risks of releasing exotic biological control agents of arthropod pests. *Annual Review of Entomology* 51, 609–634.

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Communicating Risks and Benefits of Weed Biological Control in Natural Ecosystems

A paper by Brian van Wilgen, Cliff Moran and John Hoffmann in *Environmental Management*[1] which is primarily aimed at those involved in the preservation or improvement of natural ecosystems, also provides a useful aide memoire for biocontrol practitioners dealing with actual or potential collaborators who are unfamiliar with biological control. It lays out arguments for routinely considering weed biological control as a management strategy, and discusses common doubts related to its risks in the context of other management options including doing nothing. While weed biological control may not always be appropriate, it may be the optimal or even the only viable option.

After first outlining the history of classical weed biological control, the authors explore changes in perceptions since the 1980s, identifying two main events that have undermined confidence: (i) the spread of the South American cactus moth, *Cactoblastis cactorum*, from the Caribbean (where it had been introduced in the 1950s to control native cacti) to the southern USA and Mexico, a pathway that was overlooked when the Caribbean introduction was made; and (ii) the non-target impacts of the weevil *Rhinocyllus conicus*, which was introduced into the USA in the late 1960s against European *Carduus* thistles but has also attacked native species, an outcome that had been predicted but considered then to be of lesser importance. From today's standpoint both were ill-advised introductions, but contemporary societal norms were different and the introductions were made following the due processes of the time.

These two cases aside, there have been few and mostly transient instances of non-target attack, and these have been very rare when judged against the numbers of weed biocontrol agent species and introductions. The authors argue that biocontrol scientists are themselves partly to blame for some of the negative perceptions of their science because of how success has been measured: the focus should be on measuring reductions in distribution, density and rate of spread of the weed, and also on the economic impact of control which is what decision makers understand. Post-release monitoring has generally focused on indirect evidence of success such as agent establishment, fluctuations in agent populations and measures of damage to the target weed, and thus there are relatively few convincing long-term data sets supporting accounts of successful programmes.

While the authors suggest that the evaluation of the outcomes of weed biological control should be holistic, aiming for "an environmental balance sheet", they agree that limited funding and government/agency priorities mean that it cannot be this comprehensive. They suggest that "a pragmatic and constructive approach" would be to investigate thoroughly when non-targets *are* attacked, learn from these instances and develop ways of preventing recurrences. They also argue that more and better engagement with stakeholders, especially those involved in management and conservation, "would have lessened the degree of apprehension that now detracts from the science [of weed biological control]."

The authors then turn to assessing risks and refer to three key papers papers[2,3,4] that lay out the risks and benefits involved in practising weed biological control. They explain the precautionary principle, and go on to discuss why the current emphasis on risk has become counter-productive: it has led to potential problems being exaggerated; the effect of doing nothing being underplayed; no alternative strategies are proposed if biological control is judged too risky; and it has also "led to arguably unrealistically stringent safety and approval requirements" with consequent delays or complete log-jams. The authors agree that worries arise because while host specificity and efficacy can be determined with confidence, other concerns cannot (e.g. disruption of food webs, hybridization, evolutionary/physiological change, unanticipated spread). The existence of one or more of these risks should not mean that the biocontrol agent should be rejected, rather "a decision needs to be made in every case about whether the chances of success are worth the risks".

Risk aversion is explored in some detail because, as the authors say, default risk aversion arises from a failure to realise that doing nothing is a conscious decision and also carries risks, which is very pertinent when dealing with an invasive weed. They catalogue three types of behaviour that could arise in dealing with invasive alien plants and biological control: (i) certainty bias, where one option is described in a way that makes it seem the safest option (e.g. not releasing cf. releasing an agent); (ii) status quo bias, which favours the status quo (e.g. not to release) because all outcomes are uncertain; and (iii) discounting, where immediate risks (non-target effects) are given greater weighting than something that happens later (the weed spreading). The authors also outline how biological control still has a place when an invasive species delivers economic or other benefits, and stress the importance of assessing the perceived benefits in relation to the costs of the plant.

Biological control is not alone in carrying risks, and the authors argue that other control options (including doing nothing) should be subjected to assessments of both risk and sustainability. They conclude the paper by maintaining that, while restoration of pristine ecosystems is not a realistic aim, when other measures have failed biological control may offer the most cost-effective means, and the only sustainable option, for protecting or partially restoring invaded ecosystems. They argue that where ecosystems are severely and irreversibly degraded, giving undue weight to risks of using biological control is misleading, and even unethical.

[1]van Wilgen, B.W., Moran, V.C. and Hoffmann, J.H. (2013) Some perspectives on the risks and benefits of biological control of invasive alien plants in the man-

agement of natural ecosystems. *Environmental Management* (online 14 June 2013). DOI: 10.1007/s00267-013-0099-4

[2]McEvoy, P.B. and Coombs, E.M. (2000) Why things bite back: unintentional consequences of biological control. In: Follett, P.A. and Duan, J.J. (eds) *Non-target Effects of Biological Control.* Kluwer, Boston, Massachusetts, pp. 167–194.

[3]Sheppard, A.W., Hill, R., DeClerck-Floate, R.A., McClay, A., Olckers, T., Quimby, P.C. and Zimmermann, H.G. (2003) A global review of risk–benefit–cost analysis for the introduction of classical biological control agents against weeds: a crisis in the making? *Biocontrol News and Information* 24, 91N–108N.

[4]Sheppard, A.W., van Klinken, R. and Heard, T. (2005) Scientific advances in the analysis of direct risks of weed biological control agents to non-target plants. *Biological Control* 35, 215–222.

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How Strawberry Guava Biocontrol was Derailed in Hawaii

Well-intentioned, carefully researched plans to control invasive plant species using classical biological control may sometimes be threatened by conflicts of social values. What happened when the US Forest Service proposed introducing a host-specific biocontrol agent against the invasive plant *Psidium cattleianum*, strawberry guava, in Hawaii is examined as a case study by Keith Warner and Frances Kinslow in the journal *Public Understanding of Science*[1].

From the biocontrol scientist's perspective, most of the strawberry guava story will seem familiar. Horticulturalists introduced the plant to Hawaii in 1825. It escaped cultivation to become a vigorous invader of forests, forming monotypic stands with impacts on native understorey plants and associated fauna. It was identified as a serious weed in 1954. It also acts as an alternate host of fruit flies which are quarantine pests in Hawaii with impacts on export trade. Scientists identified biological control as the only viable strategy and a classical biological control programme was initiated in 1988 with surveys in Brazil, the plant's area of origin. A scale insect, *Tectococcus ovatus*, was discovered in 1993 which causes galls on leaves, premature ageing of leaves, and decreased vigour and flowering. It is easy to culture and handle and can produce multiple generations per year. When host-specificity testing indicated it to be host specific there were grounds for optimism and a draft environmental assessment (EA) was prepared. By 2008, permission to release had been granted at national (APHIS; Animal and Plant Health Inspection Service) and state (Hawaii Department of Agriculture) levels, but then the programme stalled. For releases on state land, Hawaiian legislation requires permission to be granted at county as well as national and state level, and on Hawaii Island (Big Island) there was a late surge of opposition.

There had seemed to be little public interest in the project for most of its duration despite daily newspapers covering its progress regularly, including reporting on the national and state permits. It was only days before the public comment period for the EA ended that a paid display newspaper advertisement called for opposition to the release. Comments then began to flood in and a public information meeting was convened by the Hawaiian state government at which scientists were allowed to state their case and respond to written questions[2]. Despite this effort, the sudden public opposition did not waver and Hawaii County Council passed a resolution asking for a ban on biocontrol agents "for any tree species related to the ohia *Metrosideros polymorpha* including all species of the family Myrtaceae such as the strawberry guava". Although testing had indicated that none of 18 species of Myrtaceae in Hawaii, including *M. polymorpha*, were attacked, and Maui County Council subsequently endorsed the use of biological control in a resolution naming strawberry guava among other invasive weeds, the introduction of *T. ovatus* was halted while a new EA was prepared.

According to Warner and Kinslow, the hiatus was largely the result of one activist's counter-campaign (www.savetheguava.com/) and they explore how the opinions of this individual came to have so much influence. They identify several broad elements that he was able to exploit: (i) the extent to which local opinions and values were at odds with those of conservation scientists and government, (ii) a legacy of public distrust of government and scientists, and (iii) the public's lack of understanding of the impact of alien species, the science of biological control and how to evaluate risk.

Warner and Kinslow describe the gap between perceptions of strawberry guava: conservation scientists were united in seeing it as a major exotic invasive weed and any threat to biodiversity and risk from the biocontrol agent were evaluated within this framework, a view that government agencies subscribed to. Some local opinion held strawberry guava to be part of the forest landscape and a resource for food and wood. The rights of indigenous people are enshrined in Hawaii in laws pertaining to lands and cultural preservation, but in this case their interests were not understood and, for whatever reason, they were insufficiently engaged.

New Zealand has developed a much admired system[3] which bears examination in this context. Biocontrol agent introductions come under the Hazardous Substances and New Organisms (HSNO) Act of 1996, administered by the Environmental Protection Agency (EPA). This comprises an Authority, which is the decision-making body; and an Agency to facilitate applications, manage the regulatory process and make recommendations to the Authority. Alongside this sits a Maori advisory board which helps to ensure that decisions adhere to the principles of the 1840 Treaty of Waitangi, the country's guiding document. Over a period of 14 years, 22 biocontrol agent species, 18 for weeds and four for insect pests, were approved for release under the HSNO Act and none refused. There are many reasons why the New Zealand system is considered by many to be the best in the world but public participation, including a meaningful role for the indigenous people, is an important feature of what is a transparent and public decision-making process.

This contrasts with Hawaii where a previous debacle over fencing to protect vulnerable forest from feral pigs without the recommended consultation led to access to migration corridors and hunting grounds being blocked. Although fencing was subsequently put under tighter control, conservation science had by then come to be viewed by the (dis)affected community as a means by which 'outsider' government agencies justified decisions that conflicted with traditional forest use. This distrust of government and by extension its agencies and scientists was exploited by the 'Save the guava' campaign to slant the argument from assessing the risk from the biocontrol agent to a referendum on the credibility of the government, with the message that it was putting free wild food under attack. The common perception of plants, and trees in particular, as 'good' and insects as 'bad', especially if they are exotic (an idea the government itself was responsible for fostering as part of its efforts to educate the public about exotic pest insect species) added to the campaign argument.

Much of the text for the 'Save the guava' campaign was drawn from the EA itself. Such documents lay out all concerns about a proposed introduction and provide evidence from which conclusions are drawn and readers can make judgments. It is tacitly assumed that the reader will not come to the document with an agenda, but they are written as a scientific report which may be difficult for a lay public to interpret. Warner and Kinslow present evidence that the activist quoted selectively from the EA to form a narrative that tapped into local concerns but was directly contrary to scientific findings. They point out that scientists tend to misperceive the lay public's understanding of science and risk, and that their case study raises critical questions about public understanding of invasive species science.

Again drawing on the New Zealand experience, its HSNO decision-making body is independent (although members are appointed by government) with its autonomy designed to ensure it remains free from political, economic or activist influences. Keith Warner comments that "HNSO's approach assigns the scientist the role of expert, while a public land management agency is the advocate for an introduction. This approach is more ethical and practical." There is also a focus in the New Zealand legislation on transparency at all stages, with the Agency acting to build trust between the public, the applicants and the authorities, and this is seen as an ongoing process.[3] For example, the EPA has recognized that interacting with government agencies can be daunting, and, as well as striving to make documentation as readable as possible, is currently placing more emphasis on working with stakeholders outside formal channels in the hope this "allows more freedom for discussion and the ability to generate genuine dialogue."

In Hawaii, funding for outreach on strawberry guava had been limited but, recognizing a conflict of social values, the US Forest Service had sought to make its research public, posting the EA on its website and interacting with stakeholder groups, while Hawaii's conservation network also expended resources in communication. Arguably neither reached the people subsequently swept up in the 'Save the guava' campaign. Warner and Kinslow say that it is impossible to judge whether a different approach might have had different results, but they suggest that a two-way process of public engagement would be more responsive to community concerns. This would entail recognizing that the public holds views and seeing engagement as a process of mutual learning about societal values and science, followed by consensual decision making. Unless scientists can convince the public that a weed is causing harm, control will not be supported. Warner and Kinslow also suggest that public engagement may be able to anticipate public concerns because learning about local value predispositions that shape perceptions of management actions would enable an understanding of the circumstances in which the public might support an action that could otherwise be opposed. They suggest that spending on invasive species management needs to be realigned to create the budgets necessary for such public engagement.

Although the strawberry guava story has moved on since the period that Warner and Kinslow's case study covers (a new EA has been prepared and finalized), Keith Warner feels that there is an important lesson for biocontrol scientists to learn. The importance of 'engagement', as described above, is part of it. We need to recognize our place in the process: as expert witnesses, but not the only witnesses, and definitely not judge and jury too.

[1]Warner, K.D. and Kinslow, F. (2013) Manipulating risk communication: value predispositions shape public understandings of invasive species science in Hawaii. *Public Understanding of Science* 22(2), 203–218.

[2]Tummons, P. (2008) Waiawi biocontrol controversy. *Environment Hawai'i* 19(1). www.environment-hawaii.org

[3]Hill, R., Campbell, D., Hayes, L., Corin, S. and Fowler, S. (2011) Why the New Zealand regulatory system for introducing new biological agents works. *Proceedings of the XIII International Symposium on Biological Control of Weeds*, pp. 75–83.

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