Keynote

Opportunities and constraints for classical weed biocontrol in developing countries

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Classical biological control is one of the foremost activities to be considered for tackling invasive weeds. This technology has become well entrenched in many developed countries located in temperate regions such as Australia, Canada, New Zealand, South Africa and the USA, but its adoption and implementation in developing countries predominately located in the tropics is limited and lacks momentum.

Opportunities for biological control of weeds in developing countries is as abundant as in developed countries. Historically, the first documented example of biological weed control involved *Opuntia monacantha* (Willd.) Haw. (Cactaceae), which was introduced to India from the Americas in the eighteenth century for production of cochineal dye. However, because of the mismatch of the host plants and the dye-producing cochineal insects, the cactus became invasive and occupied a vast area stretching from Punjab to Assam in northern India. In 1795, a cochineal insect, *Dactylopius ceylonicus* (Green) (Hemiptera: Dactylopiidae), was introduced from Brazil for cochineal dye production, which did not contribute much to the cochineal dye industry, but killed the cactus and effectively cleared it from the infested area. Even though it was not a deliberate attempt of biological control of a weed, it brought the potential of classical biological control of weeds to light (Pruthi, 1969). Subsequently, based on this success, *D. ceylonicus* was introduced to Sri Lanka from India around 1865 for control of *O. monacantha*, constituting the first international transfer of a natural enemy for biological control of a weed (Goeden, 1988).

Either the serendipitous control of *O. monacantha* in 1795 in India or the intentional introduction of *D. ceylonicus* from India to Sri Lanka around 1865 should be considered as the first biological control of weed activity in the world. However, there are several publications in the literature of the biological control of weeds that wrongly report the introduction of natural enemies of *Lantana camara* L. in 1902 into Hawaii as the first instance in history.

Developing countries, in general, lack financial, institutional and human resources to take up exploration, host specificity screening and regulatory policies for primary biological control activities, but they are very amenable for technology transfer, as is, for instance, being done in Ethiopia. USAID is funding implementation of biological control of *Parthenium hysterophorus* L. (Asteraceae) in Ethiopia, transferring technologies developed in Australia and South Africa with minimal research activities on host specificity screening of local plant species and training local scientists. It also established collaboration between scientists from the USA, Australia and South Africa with scientists in Ethiopia, Kenya, and Uganda. Several such collaborations occurred in the past on many invasive weeds such as *Ageratina adenophora* (Spreng.) R. M. King & H. Rob. (Asteraceae), *Chromolaena odorata* (L.) R. M. King & H. Rob. (Asteraceae), *Eichhornia crassipes* (Mart.) Solms (Pontederiaceae), *Lantana camara* L. (Verbanaceae), *Mimosa diplotricha* C. Wright (Mimosaceae), *Opuntia* spp., and *Salvinia molesta* D.S. Mitch. (Salviniaceae), to name a few, and currently some are ongoing.

Most biological control of weeds programs in developing countries are sporadic, predominately conducted with external assistance and little or no follow up. For example, biological control of *L. camara* in Ghana, West Africa, began in 1971 with the assistance of the International Institute for Biological Control

(IIBC, now CABI). Of the five natural enemies introduced (*Diastema tigris* Guenée [Lepidoptera: Noctuidae], *Leptobyrsa decora* Drake [Hemiptera: Tingidae], *Octotoma scabripennis* Guérin-Méneville [Coleoptera: Chrysomelidae], *Teleonemia scrupulosa* Stål [Hemiptera: Tingidae], and *Uroplata girardi* Pic [Coleoptera: Chrysomelidae]), the first two did not establish and the last three established (Winston et al., 2014). After 1973, no follow up or consideration for additional agents was given.

In Tanzania, East Africa, four natural enemies were introduced with the assistance of IIBC. In 1958, *T. scrupulosa*, and in 1967, *U. girardi* were introduced and established. In 1967–68, *D. tigris* and *Salbia haemorrhoidalis* Guenée (Lepidoptera: Pyralidae) were introduced, but they failed to establish. Since then, no further activity on biocontrol of *L. camara* has been carried out (Winston et al., 2014).

In Zambia, Southern Africa, *T. scrupulosa* was introduced in 1962 by the Ministry of Agriculture, but it did not establish. In 1969, IIBC introduced *T. scrupulosa* and *U. girardi*, and in this case, the first established and the second did not. In 1970, introductions of *D. tigris* and *S. haemorrhoidalis* by IIBC, and *L. decora* and *Teleonemia elata* Drake (Hemiptera: Tingidae) by CSIRO, Australia did not establish (Winston et al., 2014). Here, too, no additional work has been carried out since 1970.

In India, most of the biocontrol activities for *L. camara* were carried out by local government agencies. The program started in 1918 with a survey of local natural enemies by Rao (1920) supported by the Government of India, while the sequence of introduction of natural enemies progressed from *Ophiomyia lantanae* (Froggatt) (Diptera: Agromyzidae) in 1921 by the entomologist in the State of Mysore (Subramanyam, 1934), to *T. scrupulosa* in 1941 by the Forest Research Institute at Dehra Dun (Roonwal, 1952), to *D. tigris*, *U. girardi* and *S. haemorrhoidalis* from 1968–1969 by the CIBC and supplied to the Central Plant Protection Institute in Hyderabad (Rao et al., 1971), to *O. scabripennis* and *U. girardi* in 1971 and *L. decora* in 1977 by the Forest Research Institute, Dehra Dun. Of these introductions, *L. decora*, *D. tigris* and *S. haemorrhoidalis* did not establish, and not all established species were widely dispersed in India (Muniappan and Viraktamath, 1986; Winston et al., 2014). Even though the program was carried out for about 50 years, there was limited coordination between the agencies and the weed is still a serious problem.

Misinformation on biological control activities in developing countries is mostly unattended and not corrected. For example, Winston et al. (2014) mentioned that *Insignorthezia* (*Orthezia*) *insignis* (Browne) (Hemiptera: Ortheziidae) was introduced to India from Hawaii*. Also, Julien and Griffiths (1998) stated Sri Lanka to be the source for the introduction of this insect to Hawaii. Both of these statements require substantiation. One of the common names of *I. insignis* is Kew bug and it was accidentally introduced from Kew Gardens in England to the Botanic Garden in Perdeniya, Sri Lanka in 1893 (Rao, 1920). From Sri Lanka, it was accidentally introduced to Nilgris, India in 1915. It is worth checking whether Kew Gardens, the West Indies or Sri Lanka are the source of introduction of *I. insignis* to Hawaii.

There is a need to address conflicts emerging in developing countries from the activities of scientists in developed countries. For example, *Opuntia ficus-indica* (L.) Mill. (Cactaceae) is cultivated for food and fodder in Ethiopia, Israel, Lebanon, Morocco and other countries in North Africa and the Middle East. *Dactylopius opuntiae* (Cockerell) (Hemiptera: Dactylopidae) was released in Saudi Arabia in 2010 and Kenya in 2014 for control of *Opuntia stricta* (Haw.) Haw. (Cactaceae). To protect *O. ficus-indica* from *D. opuntiae*, Israel imported and released a lady beetle, *Hyperaspis trifurcata* Schaeffer (Coleoptera: Coccinellidae) in 2017 (Protasov et al., 2017). Scientists involved in biological control of the cactus *O. stricta* and the cochineal insect *D. opuntiae* should communicate, address interests of individual countries and the region, and prevent counterproductive activities. The recently formed IOBC Global Working Group on Management of Cactus Species will hopefully address this conflict and confirm an amicable solution.

*This error has since been corrected in the online version of the weed biological control catalog (https://www.ibiocontrol.org/catalog/).

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