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Biological Control of Homopteran Pests of Conifers in Africa

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Introduction

Planted forests account for less than 4% of total forest area globally, but their importance is increasing along with concerns about the sustainability of harvesting natural forests. In Africa, planted forests covered about 5.7 million ha in 1995, around 5% of the world total. The African countries with the largest areas are South Africa, Morocco, Tunisia and Libya, together accounting for over half the total, but another 16 countries have 0.1 million ha or more. As in other tropical and subtropical regions, *Pinus* and *Eucalyptus* are the most planted genera, but *Acacia* is also important.

Monocultures of exotic trees are prone to pest attack, and increased global travel and trade increases the risk of introduction of exotic pests. This chapter describes biological control of three such pests of conifers in Africa, the cypress aphid, *Cinara cupressivora* Watson and Voegtlin (Homoptera, Aphididae), the woolly adelgid, *Pineus boerneri* Annand (Homoptera, Adelgidae), and the black pine aphid, *Cinara cronartii* Tissot and Pepper (Homoptera, Aphididae).

Plantation forestry has been considered a particularly appropriate target system for 'classical' or 'introduction' biological control for a number of reasons. First, the value increment per year is often relatively low, making regular interventions such as chemical control economically unviable, while biological control also offers the prospect of a permanent solution. Second, the long rotation time means that changing tree species or provenance is expensive and/or slow (although there are a number of examples of this approach in Africa).

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Third, it is reasoned that the environmental stability of a forest is likely to be more conducive to biological control, although the evidence suggests that this applies more to the establishment of agents than to the magnitude of their impact on target pests (Hall *et al.*, 1980).

Murphy and Day (1998) re-analysed the data from Greathead and Greathead (1992) focusing on biological control of tree pests. At that time, 43 agents had been introduced against 17 pest species, with 15 out of 35 projects judged to be successful. Greathead and Greathead (1992) had shown that Homoptera is the order most frequently and most successfully targeted with introduced natural enemies.

Cinara cupressivora

The cypress aphid, *C. cupressivora,* was first reported in Malawi in 1986 but, within a relatively short period, spread to many countries in eastern and southern Africa (Mills, 1990; FAO, 1991). Initially the pest was identified as *Cinara cupressi* (Buckton). However, recent studies have shown that aphids previously identified as *C. cupressi* actually belong to a species complex (Watson *et al.*, 1999). These authors conducted morphometric analyses of material from different regions around the world, studied host plant range, parasitoid records and host associations and revealed that the species causing problems in Africa was *C. cupressivora*. Watson *et al.* (1999) also hypothesized that the native range of this species is most likely the region from eastern Greece to just south of the Caspian Sea. *C. cupressivora* is now widely distributed throughout eastern, central and southern Africa, the margins of western Europe, countries bordering the Mediterranean Sea, the Middle East, Yemen, Mauritius and Colombia. The taxonomic complexity of the group indicates that caution is required when interpreting earlier literature, particularly with respect to western Europe and the Mediterranean region.

In Africa, *C. cupressivora* develops throughout the year producing both apterous and alate populations largely in response to changes in density and host plant quality. Previous studies have elucidated the basic developmental and reproductive biology of the aphid (Kairo and Murphy, 1999a). The aphid is highly aggregative and exploits a wide range of feeding sites ranging from green branches to woody stems. Damage is characterized by dieback, and heavy infestations can cause the death of mature trees. In Africa, *C. cupressivora* attacks a wide range of Cupressaceae, including indigenous species such as Mulanje cedar, *Widdringtonia cupressoides* (L.) Endl. (the national tree of Malawi) and *Juniperus procera* Hochst. ex Endl., an important tree in many water catchment areas in Kenya. In most countries, however, the greatest damage is on exotic plantation or ornamental species, particularly the Mexican cypress, *Cupressus lusitanica* Mill, an important plantation tree grown in large monocultures.

By 1991 it was estimated that the aphid had killed US$41 million worth of trees in Africa, and was causing an annual loss of growth increment worth US$13.5 million (Murphy, 1996). Orondo and Day (1994) reported 12% mortality to an old seed stand of *C. lusitanica* in Kenya, but also noted that some severely damaged trees were recovering.

A range of options for managing *C. cupressivora* was initially considered that included chemical control, the use of resistant varieties and silvicultural techniques. However, it was clear from the outset that biological control was the most promising option (Mills, 1990). Discussions in several regional workshops held during the early 1990s arrived at the same conclusions (FAO, 1991).

A biological control programme commenced in 1991, spearheaded by CAB *International* in collaboration with several national and regional agencies. At that time the pest's native range was not certain, and there was uncertainty with regard to the taxonomic status of two closely related North American species. Against this background, exploratory surveys covered a broad geographical range including Mexico, USA, Europe, North Africa and Pakistan. Aphid specimens were also collected for more detailed biogeographical studies. Exploratory surveys focused on parasitoids since these were more likely to have narrow host ranges and thus a greater chance of satisfying requirements for safety with respect to non-target impact (Murphy *et al.*, 1994). Subsequent to clarification of the taxonomy of the group, additional surveys were undertaken in Syria.

Parasitoids were collected from several species in the sub-genus *Cinara Cupressobium* feeding mainly on *Cupressaceae* including, *Cinara fresai* Blanchard, *Cinara juniperi* de Geer and material that is now known to belong to the *C. cupressi* complex. Four species of parasitoids, all in the genus *Pauesia* (Hymenoptera, Braconidae) were assessed. Of these, *Pauesia juniperorum* (Starý) (Plate 17) showed the greatest promise, and it was introduced into Africa following quarantine assessment and screening at CAB *International*, UK. Like other aphidiines, *P. juniperorum* is a solitary endoparasitoid. It attacks all stages of *C. cupressivora,* but development is best in older hosts (>9 days old) (Kairo and Murphy, 1999b). Several other *Pauesia* spp. collected on *Cinara* spp. on pine were also assessed, but none parasitised *C. cupressivora.*

Pauesia juniperorum was first described by Starý (1960) from specimens reared out of *C. juniperi.* The species is widely distributed in mountain and sub-mountain habitats of Europe, mainly on *Juniperus* spp. and *Cupressus macrocarpa* Hartw. ex Gordon. Field host records include, *C. juniperi*, *C. fresai, C. ?fresai* and *C. cupressivora.* Populations of *P. juniperorum* were collected from *C. cupressivora* in England and *C. fresai* in France and England. While the parasitoid was recovered from *C. cupressivora*, it was more commonly found attacking *C. fresai.* Based on more recent knowledge on the distribution of *C. cupressivora*, it seems likely that the preferred host is *C. fresai* and the association with *C. cupressivora* is recent.

Prior to the introduction of *P. juniperorum* into Africa, a dossier was prepared to support applications to the national regulatory authorities, along the lines prescribed by the Code of Conduct for the Import and Release of Exotic Biological Control Agents (FAO, 1996), although at that time the code had not yet been published. The first shipments were made to Kenya in 1993, and the import permit was granted under the conditions that the insects be held in quarantine, and host-specificity tests conducted to demonstrate that it would not attack coccinellids, predatory mites or other local conifer aphids. Permission for field releases was granted in 1994 following presentation of a report on quarantine and host-specificity testing, during which the insect was cultured for nine generations. In Malawi and Uganda, permission for direct releases was granted on the basis of the same dossier. The first releases were made in Malawi and Kenya in 1994, and in Uganda in 1995. Repeated releases of small numbers (<500 wasps) were made over a period of 1–2 years in all three countries. Following more than a year of releases in Malawi, there was no evidence of establishment, but initial results in field cages were encouraging (Chilima *et al.*, 1995). Further releases were made in 1995, and the following year establishment was confirmed on both *C. lusitanica* and *W. cupressoides*. Establishment was slower in Kenya and Uganda. The last releases were made in late 1996 with no sign of establishment, but in early 1999 the parasitoid was found in both countries, over 2 years after it had last been seen in the field.

P. juniperorum is now widespread in Malawi and Kenya, and impact assessment has commenced in Kenya. The severity of damage by the aphid has declined in both countries, but this cannot definitely be attributed solely to the action of *P. juniperorum,* as some reduction in the aphid population had been noted in Kenya even before the agent was released.

Several studies have shown potential for the use of plant resistance and/or tolerance as part of an IPM strategy for cypress aphid. In a study on the variation and inheritance of resistance in *C. lusitanica* against *C. cupressivora*, Kamunya *et al.* (1997) found a marked variation in aphid survival both between and within host tree families. They demonstrated an individual-tree narrow-sense heritability of 0.76 ± 0.30, indicating strong additive genetic control and suggesting that potential exists for selection and breeding for resistance. These conclusions have been corroborated by other studies on *C. lusitanica* in Kenya and Tanzania (Mugasha *et al.*, 1997; Kamunya *et al.*, 1999).

Chemical control has been used, but in most circumstances it is prohibitively expensive and logistically difficult in plantations. Ornamental trees and hedges have been sprayed in towns; for example; in Mauritius methamidophos has been applied with motorized mistblowers.

Pineus boerneri

Pineus spp. are native to the temperate zones of the northern hemisphere. All species feed on conifers and produce a characteristic white, woolly covering. The most acute pest problems have been caused by the introduction of two species, *Pineus pini* (Macquart), which is indigenous to Europe, and *P. boerneri* into countries of the southern hemisphere. *P. boerneri* has been reported as a pest of pines in East, Central and southern Africa. It was described from *Pinus radiata* D. Don in California (Annand, 1928), but possibly originates in East Asia, where it has been recorded under the name *Pineus laevis* (Maskell) (McClure, 1984). Their complex polymorphic life cycles, a shortage of distinctive taxonomic features and the use of various synonyms have caused great confusion over the true identities and origins of these two species. For example, *P. boerneri* has been recorded under the name of *P. laevis* Gmelin (Australia, New Zealand and Hawaii), *Pineus havrylenkoi* Blanchard (South America) and

P. pini (East Africa). A study by Blackman *et al*. (1995) clarified the taxonomic status of pest *Pineus* spp. They showed that the African species, first reported as *P. pini* from Kenya and Zimbabwe in 1968 (Mills, 1990), shows closer affinity to *P. boerneri*. These findings substantiate the suspicions first raised by Barnes *et al.* (1976) that *P. boerneri* was probably accidentally introduced into Zimbabwe on *Pinus taeda* L. scions from Australia in 1962.

Heavily infested trees develop yellowing needles prior to needle drop, shoot death and dieback of growing tips. Infested needles are reduced in length, and this can lead to a loss of up to 50% of growth increment under warm dry conditions (Mailu *et al.*, 1978). Young and stressed trees are more prone to infestation and, under some circumstances, heavy infestations can lead to tree death. The impact of *P. boerneri* on wood production has been investigated in several countries. Up to 20% tree mortality was reported from *Pinus* spp. research plots in Kenya (Odera, 1974), and studies in Tanzania found that the shoots and stems of infested *Pinus patula* Schiede ex Schltdl. & Cham. seedlings lost 20.9% of their dry weight after 24 weeks (Madoffe and Austara, 1990). Pine cones are also damaged; in one study 31.8% of *Pinus pinaster* Aiton cones were infested and the seed yield from affected cones was reduced by 71.7% (Zwolinski *et al.*, 1989).

Classical biological control programmes have been implemented against *Pineus* spp. in a number of countries worldwide. Research carried out for these programmes has identified a range of insect predators of *Pineus* spp. but there are no known parasitoids. Several of these predators have been introduced as biological control agents. The most successfully utilized have been the specialized *Leucopis* spp. (Diptera, Chamaemyiidae) which have been credited with the control of outbreaks of *Pineus* spp. in Hawaii, New Zealand and Chile. During the 1970s, various predators (Table 7.1) were introduced into Kenya and Tanzania to control *P. boerneri.* These included *Scymnus* spp. (Coleoptera, Coccinellidae) and *Leucopis* spp., but reports indicate that all failed to establish (EAAFRO, 1970–1976; KARI, 1977–1980). In 1975, *Tetraphleps raoi* Ghauri (Hemiptera, Anthocoridae) was introduced to Kenya (Mailu *et al.*, 1980) and Tanzania (FAO, 1991) and has established in both countries.

In 1991, further biological control activities against *P. boerneri* were initiated with the aim of redistributing *T. raoi* and/or introducing *Leucopis tapiae* Blanchard. However, before any introductions of *Leucopis tapiae* could be made, it was found attacking *P. boerneri* in Malawi. It appears to have established either as a result of the previous introductions in East Africa in the 1970s, or by accidental introduction on imported pines. As there is no evidence for its presence in Kenya where it had been released, the latter explanation is perhaps more likely. *T. raoi* was introduced to Uganda (1996–1997) and Zambia (1996) from Kenya; in both cases direct releases were permitted on the basis of a dossier.

Predator exclusion studies conducted by Mailu *et al.* (1980) on pest populations of *P. boerneri* in Kenya concluded that eight species of indigenous predators (mainly coccinellids) killed about 12% of *P. boerneri* in the field. Unfortunately, any additional mortality due to *T. raoi* was not established. A later field experiment in Kenya failed to demonstrate the impact of *T. raoi*, perhaps because high

Table 7.1. Predators introduced into Kenya and Tanzania in the 1970s as potential biological control agents of *Pineus boerneri* Annand.

Predator species	Origin	Imported	Released	Established
Chamaemyiidae				
Leucopis argenticollis Zetterstedt	India	Kenya 1975	No	No
Leucopis manii Tanasijtshuk	India	Kenya 1975 and 1977	No	No
		Tanzania 1970s	?	?
Leucopis nigraluna McAlpine	Pakistan	Kenya 1974–1977	Yes	No
		Tanzania 1970s	?	?
Leucopis tapiae Blanchard	Europe	Kenya 1972	Yes	? No
		Tanzania 1970s	?	?
Leucopis spp.	Austria	Kenya 1971	Yes	? No
	India	Kenya 1978–1979	?	?
Coccinellidae				
Scymnus suturalis Thunberg	Austria/ Germany	Kenya 1971–1972	Yes	?
Scymnus nigrinus Kugelann	Austria	Kenya 1971–1972	No	No
Anthocoridae				
Tetraphleps raoi Ghauri	Pakistan	Kenya 1975	Yes	Yes
		Tanzania 1975	Yes	Yes

?, unknown.
Sources: EAAFRO (1970–1976); KARI (1977–1980); Mills (1990); Blackman *et al.* (1995); Greathead (1995).

levels of between-tree variability in *Pineus* populations caused experimental difficulties. The *T. raoi* released in Uganda are thought to have established, but there is no information on the outcome of the releases in Zambia.

There are two principal options for control of *Pineus* spp. in Africa apart from biological control: the application of insecticides and silvicultural techniques. In Kenya, experimental control of *P. boerneri* was achieved with both 0.075% benzene hexachloride and 0.05% dimethoate (FAO, 1991), and in Tanzania Thiodan (endosulfan) and Teepol (a detergent) 1% solution, and propoxur (Baygon E.C.) were effective (FAO, 1991). However, aside from being environmentally undesirable, chemical control of *P. boerneri* is costly and not feasible on a large scale.

Silvicultural options centre on the replacement of existing trees with different species or provenances of pines that are less susceptible to attack. However, re-planting is a long-term and possibly expensive solution that may incur hidden costs in reduced yield or quality. For example, *P. radiata* has been more or less abandoned in East Africa due to needle blight caused by *Dothistroma pini* Rostrup (*Mycosphaerellaceae*) and has been largely replaced with *P. patula*, a species less susceptible to *P. boerneri* (Barnes *et al.*, 1976), but inferior in fibre quality. Other measures include devoting more attention to the selection of suitable planting sites and to avoid placing trees under stress, a factor that can make them more vulnerable to attack.

Cinara cronartii

The black pine aphid, *C. cronartii*, is widely distributed across eastern North America, from Quebec in the north, southwards to Florida and then westwards to Texas and Arkansas (Pepper and Tissot, 1973). Its distribution closely follows that of fusiform rust disease caused by the fungus *Cronartium fusiforme* Hedge & N.R. Hunt ex Cummins (*Cronartiaceae*), a destructive disease that causes stem cankers on pine trees. The black pine aphid is not considered to be a pest in North America and lives almost exclusively in the cankers formed by this disease where it is guarded by various ant species (Pepper and Tissot, 1973).

The black pine aphid was first recorded in South Africa during 1974 (van Rensburg, 1979). Populations peak in winter (May–August), and following its appearance, it occurred annually in large numbers in pine plantations in the summer rainfall region of South Africa and Swaziland. In the summer of 1979, drought-stressed pine plantations of *P. taeda, Pinus elliottii* Engelm. (originally from the USA) and *P. patula* (from Mexico), the principal commercial timber species in the country, suffered severe damage from heavy aphid infestations as the tops of trees died back (van Rensburg, 1981). Since the costs of chemical control by aerial spraying in pine plantations are prohibitive, a biological control programme was initiated. Natural enemies of *C. cronartii* were absent in South Africa (van Rensburg, 1981), whereas at least one aphidiid parasitoid was known to attack it in the USA (Pepper and Tissot, 1973).

A survey conducted in the eastern USA in 1983 revealed a *Pauesia* sp., subsequently described as *Pauesia cinaravora* Marsh, (1991), parasitising *C. cronartii* colonies. Its biology was studied by Kirsten and Kfir (1991). A laboratory culture of this parasitoid was established in Athens, Georgia, USA, and five consignments of newly mummified aphids were shipped to South Africa (Kfir *et al.*, 1985, 2003). To prevent the possible introduction of fusiform rust into South Africa, rust-free logs were used in the aphid and parasitoid rearing facility in Athens. Before dispatching consignments to South Africa, mummies were surface-sterilized by dipping them in a 1% sodium hypochloride solution to destroy any fungal spores (Kfir *et al.*, 2003).

An import and release permit was granted on the basis of documentation submitted to a committee of experts, similar to the procedure in the present FAO Code of Conduct. The authorities required only one quarantine generation and no host-specificity tests since it was known from the literature that *Pauesia* spp. are specific to lachnids, and there are no lachnids indigenous to South Africa.

Following quarantine, logs bearing mummified aphids were transported to release sites in various pine plantations where they were suspended about 2 m above the ground in pine trees heavily infested with *C. cronartii* (Kfir *et al.*, 1985) (Plate 18). Additional releases used open-sided shelters specially erected in two pine plantations in Mpumalanga Province. The parasitoids were released directly on to heavily infested branches that had been sawn off pine trees and piled up in the shelters. There, parasitoids reproduced in large numbers before dispersing into the adjacent plantations (Kfir *et al.*, 2003).

During the winter months of 1983, a total of 210,000 parasitoids were released at eight sites in commercial pine plantations in Mpumalanga, and 16,000 were released at one site in the Kwazulu-Natal midlands. Three releases, totalling 6000 parasitoids, were also made in June 1983 in one isolated pine stand (about 1 ha in size) at the Plant Quarantine Research Station at Buffelspoort near Rustenburg. This site was approximately 250 km from the nearest commercial pine plantation, and was therefore used for intensive observations following parasitoid release (Kfir *et al.*, 1985).

In 1983, the parasitoid became established in the isolated pine stand at Buffelspoort and brought the aphid population under control (Kfir and Kirsten, 1991). Two months after the initial release, the parasitoids dispersed to another pine stand about 1 km distant that had served as a control plot (Kfir *et al.*, 1985).

In the commercial pine plantations, living aphids had completely disappeared from some trees within 4 weeks of parasitoid release, leaving only mummies. Eight weeks after release, mummies were recorded up to 500 m away from the release points, indicating successful parasitoid dispersal (Kfir *et al.*, 1985). Towards the end of winter in August 1983, it became apparent that *P. cinaravora* had successfully established in all release sites in Mpumalanga and Kwazulu-Natal Provinces.

The question whether or not the parasitoid would be able to survive the summer in South Africa was of great concern to the project. In the USA, *C. cronartii* is commonly found in the fusiform rust galls during the summer, whereas in South Africa, where this disease does not occur, the black pine aphid becomes extremely rare during the rainy season and occurs singly under the bark or subterraneously on the roots of host trees (van Rensburg, 1979). However, in April 1984, dissected aphids collected at Tweefontein plantation (Mpumalanga) were found to contain parasitoid larvae. Later dissections of field collected aphids from numerous commercial pine plantations in Mpumalanga and Kwazulu-Natal as well as from the Northern province and Swaziland revealed >80% parasitism. By 1984, maximum dispersal was up to 154 km from the nearest release site (Kfir *et al.*, 2003). By the end of July 1984, *P. cinaravora* had extended its range to the northern part of the Eastern Cape and southern parts of the Northern Province and Swaziland, all of which are in the summer rainfall region (Kfir *et al.*, 2003), and had invaded all sites.

Since the introduction of *P. cinaravora* into South Africa, substantial reduction in *C. cronartii* populations has occurred throughout all pine plantations in the summer rainfall regions of the country. Surveys to determine levels of infestation by *C. cronartii* were conducted both before and after the introduction of parasitoids. The percentage infested trees declined drastically from about 99% to 2% following the release. Infestation levels per tree also decreased markedly (Kfir *et al.*, 2003). In addition to this sharp decline in pest populations, no treetop die-off has been reported since the establishment of *P. cinaravora*. A few minor outbreaks of black pine aphid occurred annually until 1994, but were confined to relatively small areas of 1–2 ha in size. Such outbreaks were normally of short duration (1–2 months) and collapsed as parasitoid numbers increased. No outbreaks of *C. cronartii* have been reported since 1994, indicating that *P. cinaravora* has successfully controlled the black pine aphid throughout the summer rainfall region of South Africa and Swaziland. The pest is now of no economic importance and the South African Forestry Council, which funded the work, concluded that the savings in any one year far exceeded the total cost of the project (Kfir *et al.*, 2003).

Discussion and Conclusion

A homopteran pest in a perennial habitat is statistically one of the most successful scenarios for classical biological control. Of the cases described here, one was a total success, while in the other two cases agents were established, but success to date has been partial at best, although impact has not been quantified. Impact assessment is probably more difficult in partial successes and, in the case of the cypress aphid, the project ended some time before the agent had even established. If *P. cinaravora* had been slower to establish, or the impact on the pest less dramatic, would further resources have been spent on searching for additional agents or on quantifying the partial success? Similarly, if funding for further work on cypress aphid was to become available, would it be spent on impact assessment of *P. juniperorum*, or on evaluation and introduction of the potentially more effective, but unidentified, *Pauesia* species found in Syria in 1997? More well-documented impact studies are required in biological control in Africa, but with limited resources, improving control is usually the first priority.

The establishment of *P. juniperorum* was slow in comparison with that of *P. cinaravora*, and its impact much less obvious. A major difference between the two situations is the number of insects released; for *P. juniperorum* it was in the order of thousands over a period of 2 years, while over 200,000 *P. cinaravora* were released over a much shorter period of time. This may account for the success of initial establishment of *P. cinaravora*, but it is not clear why *P. juniperorum* required over 2 years to build up to detectable levels in Kenya and Uganda. The possibility that *C. cupressivora* is not the primary host of *P. juniperorum* may also have contributed to the slow establishment. A genetic comparison between the *P. juniperorum* populations now established in Africa and those in Europe could be illuminating.

The importance of taxonomy in biological control is well illustrated by the examples in this chapter. *C. cronartii* was identified soon after it was found in South Africa and its area of origin was well known, so surveys for agents could be undertaken without delay in a well-defined region. In contrast, *C. cupressivora* was initially thought to be *C. cupressi*, and only after extensive taxonomic research were its correct identity and probable area of origin determined (Watson *et al.*, 1999). This meant that the search for biological control agents extended over many regions, reducing the likelihood that an effective agent would be found. While *P. juniperorum* has now established in three countries in Africa, it is likely that its preferred host is *C. fresai* or *C. juniperi*. Had the taxonomy of *C. cupressivora* been known at the outset, the *Pauesia* species in Syria would have been found much earlier, and a different course of events might have occurred. The taxonomic confusion surrounding the identity of the woolly adelgid in Africa did not have such a marked effect on the progress of the biological control programme as candidate biological control agents were already known from elsewhere, and the pest was not of such high priority.

A key point in any biological control programme is the decision whether or not to import an agent, and if so, under what conditions. Historically, the decision focused on whether the agent was likely to be successful, and thus often large numbers of species were released against a single pest. At least eight species of *Pineus* predators were introduced into Kenya and Tanzania in the 1970s. Since that time, the potential negative impact of introduced agents has become an issue of much greater concern, and in 1996 the Code of Conduct for the Import and Release of Exotic Biological Control Agents was published (FAO, 1996), stipulating consideration of possible non-target effects.

While the general principles of the Code of Conduct were followed in the later introductions described in this chapter, it is doubtful that the large numbers of agents for *Pineus* could now be introduced, even if it was thought to be biologically desirable. The cost of preparing the necessary dossiers necessitates greater selectivity before applications for the importation of agents are made. Nevertheless, considerable differences were experienced in the conditions attached to importation of the agents used in the biological control programmes reported here. In South Africa, a single quarantine generation was required for *P. cinaravora*, primarily to eliminate potential contaminant organisms. In Kenya, with similar evidence available as for *P. cinaravora,* importation of *P. juniperorum* had much stricter conditions attached, delaying field releases by nearly a year. In contrast, Uganda and Malawi allowed direct releases on the basis that the insects originated in a quarantine facility in Europe. Thus adoption of the Code of Conduct might speed introductions of biological control agents in some cases, and slow them in others, but overall the application of more harmonized procedures should be beneficial.

In none of the three cases described here have other control methods played a significant role, so there were no issues of integrating biological control with other control tactics. For both the cypress aphid and woolly adelgid, it is clear that different species and provenances of host trees vary in susceptibility to the pests. In the long term, these approaches may provide an important complement to biological control.

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