The Southern African Plant Invaders Atlas (SAPIA) and its contribution to biological weed control

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The Southern African Plant Invaders Atlas (SAPIA) is a mapping project, launched in 1994, to collate information on the distribution, abundance and habitat types of alien invasive plants in southern Africa. The SAPIA database is a computerized catalogue of some 40 000 locality records of more than 400 naturalized alien plant species. The database incorporates records gathered by about 180 participants between 1994 and 1998 and from roadside surveys conducted by the author between 1979 and 1993. Among its many uses, SAPIA can assist biological control programmes, in particular the more recent ones, in several ways. Information on the geographical distribution and ecological requirements of invasive plants in their introduced range can ensure that biological control agents are brought from comparable habitats in their country of origin so as to optimize the chances of establishment and efficacy. Early detection of new invaders and new foci of spread allows implementation of biological control at an early stage of invasion with the potential to pre-empt severe problems. In the long term, SAPIA will also provide an historical record of the spread of invaders and can thereby be used to monitor the effectiveness of introduced biological control agents. Although biological control programmes against weeds have been ongoing in South Africa for some 80 years prior to the advent of SAPIA, baseline data generated by this initiative should prove particularly useful in the case of new programmes.

Key words: Alien invasive plants, southern Africa, mapping project, computerized database, biological control.

A precursor to the Southern African Plant Invaders Atlas (SAPIA) commenced in 1979 when alien invasive woody plants were surveyed along roadsides throughout Gauteng Province (formerly central Transvaal), South Africa (Wells *et al.* 1980). These surveys were later extended to the remainder of South Africa and were completed in 1993 (Henderson & Musil 1984; Henderson 1989, 1991a,b, 1992, 1998a). The momentum of these initiatives was maintained with the launch, in January 1994, of the first phase of the SAPIA project (Henderson 1998b). This inaugural phase, involving volunteer participants, was scheduled for a five-year period, ending in December 1998.

SAPIA is primarily aimed at the collection of basic information on alien invasive plants and records their distribution, abundance and habitat types on a 15 minute square (quarter degree) scale. The atlas region for the first phase of SAPIA covers South Africa and the neighbouring countries of Lesotho and Swaziland. The second phase of the project will be extended to other countries of the Southern African Development region (SADC) and will include Angola, Botswana, Malawi, Mozambique, Namibia, Zambia and Zimbabwe.

Information for the first phase of SAPIA is recorded on two standardized atlas sheets, with slightly different species lists, covering the western and eastern halves of the atlas region. One hundred plant taxa are listed on each sheet, with a combined total of 161 species. Provision has also been made for recording additional species, particularly new invaders. A pocket field guide that facilitates the identification of all listed species was also compiled as part of this initiative (Henderson 1995). The SAPIA database is computerized and currently includes some 40 000 records of more than 400 naturalized alien plant species (Henderson 1998b). Indeed, the distribution maps pertaining to all the weeds reviewed in this volume were generated by SAPIA. In this review, some of the ways in which this information can benefit biological control programmes in South Africa are considered.

BIOLOGICAL CONTROL AND SAPIA

Biological control programmes against alien weeds should be based on factual information on the weed's ecology and invasiveness (Harley & Forno 1992). In particular, surveys such as SAPIA can provide information that: (i) determines the geographic extent and thereby the ecological requirements of the weed; (ii) indicates the potential for further spread, and (iii) provides an historical account of the introduction and expansion of the weed. If this information is obtained before surveys for potential biological control agents are carried out, it may determine where best to explore for agents and may influence the type of agents that are eventually selected.

GEOGRAPHICAL DISTRIBUTIONS AND ECOLOGICAL REQUIREMENTS OF INVADERS

The success of a biological control programme can be detrimentally affected if agents are collected from cultivars (varieties) of the weed other than those that are being targeted. The problem becomes acute in weeds that are highly variable, such as *Lantana camara* L., because the agents may only be able to survive on certain cultivars (Cilliers & Neser 1991; Harley & Forno 1992). The time and expense spent on obtaining potential agents may be wasted if they originate from one cultivar and are then released on another that will not allow the agent to survive. The programme against *L. camara* was implemented some 33 years before the launch of SAPIA, so these problems could not be predicted at the time. However, information currently available for most of South Africa's priority invaders should prevent a recurrence of such problems when new programmes are initiated. SAPIA records the overall distribution of a weed, which allows comprehensive identification of the range of cultivars present in the country and, eventually, for agents to be released onto the correct cultivars.

At the habitat level, SAPIA can provide information on the ecological requirements of a weed and thus facilitate where suitable agents might be found in the native range of the plant. For example, specimens of *Caesalpinia decapetala* (Roth) Alston (Mauritius thorn, Mysore thorn) from South Africa are most closely matched with a cultivated specimen from India (Calcutta Botanical Garden). Ecoclimatic data extrapolated from SAPIA suggest that exploratory surveys for biocontrol agents should commence in India and concentrate on latitudes between 22° and 32° North, at altitudes of 700–1500 m and in areas with a mean annual rainfall of 750–1250 mm.

Extreme rather than average climatic conditions may influence the survival and success of biological control agents in their new habitats. The distribution of *Melia azedarach* L. (Persian lilac, seringa, 'syringa') in South Africa, Lesotho and Swaziland (Fig.1) indicates that the plant is widely naturalized but that there are areas where the weed is more invasive and reaches highest abundance. SAPIA clearly shows that *M. azedarach,* which has recently been targeted for biocontrol, is most abundant in moist and dry subtropical savanna, but has also invaded grassland. Introduced agents will thus have to endure a long dry season as well as variable annual rainfall (from 250 mm in dry years to 1000 mm in wet years) and temperatures that range from 0–40 °C.

EARLY WARNING OF NEW INVADERS OR NEW FOCI OF SPREAD

The chances of successful biocontrol are greatly increased if a weed species, or a local population, is targeted at an early stage of invasion. The biocontrol programme against *Hypericum perforatum* L. (St John's Wort) in South Africa exemplifies the benefits of pre-emptive action that prevented this plant from reaching the damaging levels observed in several other countries (Gordon & Kluge 1991). In particular, the use of seed-attacking insects at an early stage of invasion could prevent a plant from becoming invasive or, at least, slow its rate of invasion (Neser & Kluge 1986). The implementation of an early-warning system for new weeds or foci of spread could thus have considerable benefits for biocontrol.

Recent examples of pre-emptive biocontrol programmes against weeds that are in the early stages of invasion include those against *Solanum sisymbriifolium* Lam. (wild tomato, sticky nightshade), *Macfadyena unguis-cati* (L.) A. Gentry (cat's claw creeper) and *Leucaena leucocephala* (Lam.) De Wit. (leucaena, giant wattle). In addition, the SAPIA project has recorded several invasive species that are new to the southern African region but which are problematic elsewhere in the world. These include *Lonicera japonica* Thunb. var. *Halliana* Nichols (Japanese or Hall's honeysuckle), *Lythrum salicaria* L. (purple loosestrife), *Opuntia humifusa* (Raf.) Raf. (= *O. compressa* (Salisb.) Macbride) (creeping prickly pear) and *Rosa multiflora* Thunb. (multiflora rose). Some of these species have been subjected to biocontrol in other countries (Julien & Griffiths 1998), which could greatly assist future programmes in southern Africa. For example, *O. humifusa* appears to be widespread in South Africa but has never been

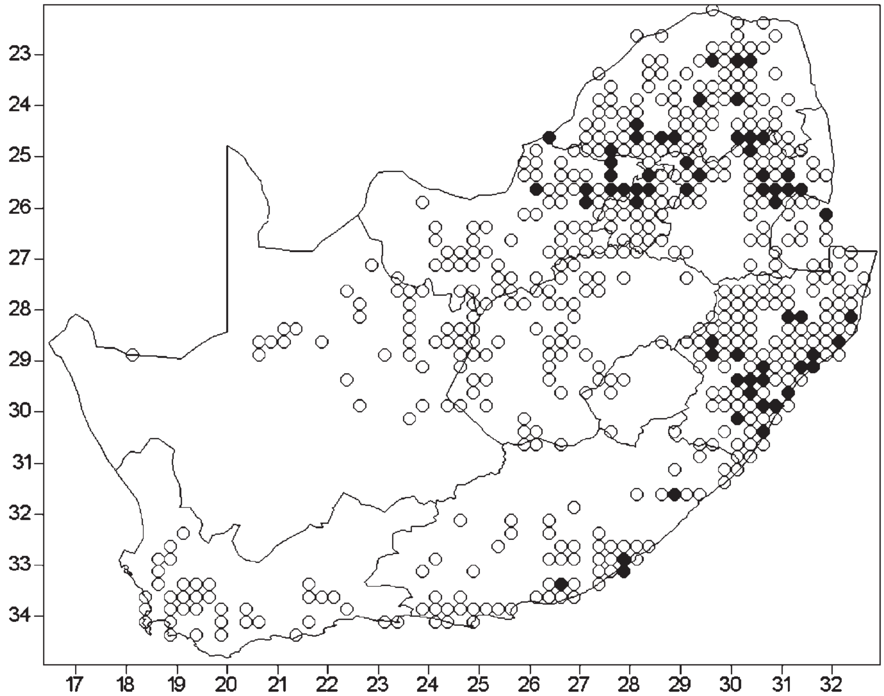

Fig. 1

Distribution of *Melia azedarach* in South Africa, recorded from 1979 to 1999, indicating areas where the plant is present (❍) and abundant (●).

described in any literature on naturalized *Opuntia* species, probably because of misidentification as *Opuntia lindheimeri* Engelm. (small round-leaved prickly pear). *Opuntia humifusa* has been controlled biologically in Australia (Hosking *et al.* 1988) and is known to be susceptible to the cochineal insect, a strain of *Dactylopius opuntiae* (Cockerell), which was introduced into South Africa in 1997 to control *Opuntia stricta* (Haw.) Haw. (Australian pest pear) (Volchansky *et al.* 1999).

SAPIA can also facilitate existing biocontrol programmes by identifying the localities where invasive species have new foci of spread. In recent years, *O. stricta* has displayed a very rapid rate of increase in South Africa, with new foci in several provinces. Following the recent biocontrol initiatives with *O. stricta,* it is very important that the cochineal insects be established at all new reported sites, particularly since they are relatively poor dispersers and are unable to colonize isolated infestations of the weed. In another example, SAPIA recently recorded a disjunct and healthy population of *Hakea sericea* Schrad. (silky hakea) in the former Transkei (now part of the Eastern Cape), which was outside the weed's normal distribution in the mountain fynbos of the Western Cape. Seed-feeding insects already established throughout the Western Cape should thus be employed to prevent further spread from this new site. New foci have also been recorded for *Mimosa pigra* L. (giant sensitive plant) and *Parthenium hysterophorus* L. (parthenium weed), both of which are potentially very troublesome invaders, and have been subjected to biocontrol elsewhere in the world (Julien & Griffiths 1998).

THE HISTORY OF SPREAD

The history of spread of an invader can be illustrated by comparing its distribution over time. Similarly, the efficacy of biocontrol agents can be determined by comparing the rates of invasion before and after their release. The distribution maps and calculated expansion rates of weeds serve as a baseline against which changes can be monitored in future years.

For example, *Azolla filiculoides* Lam. (red water fern) was first reported as troublesome in 1948 (Jacot Guillarmod 1978) and by 1980 (Fig. 2) had increased its distribution in the Eastern Cape and Free State (Anon. 1980). Comparison of these records with the latest SAPIA distribution (Fig. 2)

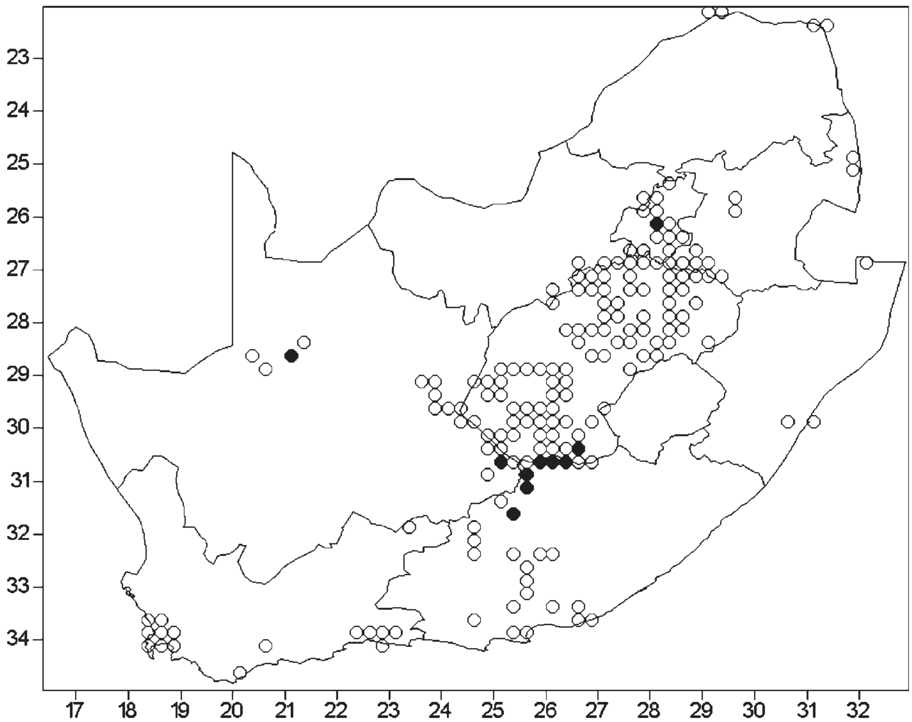

Fig. 2
Expansion of *Azolla filiculoides* in South Africa, from 1980 (●) to 1999 (❍).

suggests that *A. filiculoides* expanded its range at an average rate of 8.52 fifteen minute squares per year. However, these rates of expansion should be treated with caution as they may reflect more the increased sampling efforts than the actual increases in weed abundance. Indeed, the SAPIA initiative has highlighted awareness of weeds such as *A. filiculoides* that were mostly underrated until the 1990s. Although pre-SAPIA distributions of weeds are likely to be inaccurate (*i.e.* underestimates), the current updated information has provided a baseline against which future distributions can be more accurately compared.

Although SAPIA is at present unable to quantify the success of existing biological control programmes, particularly the earlier ones, the accurate information currently contained should facilitate such evaluations in the case of relatively new weeds onto which natural enemies have recently been released or are about to be released. In 1997, the first biocontrol agent was released against *A. filiculoides* in South Africa (Hill, this issue) and SAPIA should now be in a position to determine the ultimate effect of this programme. Other weeds against which agents have been or are scheduled to be released for the first time include *C. decapetala, L. leucocephala, M. unguis-cati* and *Solanum mauritianum* Scop. (bugweed) and SAPIA may similarly facilitate their evaluation.

CONCLUSIONS

The SAPIA database incorporates more than 40 000 records of over 400 alien plant species naturalized in South Africa, Lesotho and Swaziland. Although the information generated by this initiative may be of limited value where earlier biological control programmes are concerned, it can assist more recent programmes in several ways. These include (i) improving the chances of agent establishment and efficacy by taxonomic and climatic matching with their target plants, (ii) advancing pre-emptive biocontrol programmes by the early warning of new invaders and new foci of spread, and (iii) providing an historical monitoring mechanism that can determine the effect of introduced agents on the weeds' spread and distribution. The extension of the project to incorporate several other southern African countries can similarly enhance their biological control programmes.

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REFERENCES

ANON. 1980. Waterfern/ Rooiwatervaring. Water Plants/ Waterplante W16/1980. *Farming in South Africa.*

CILLIERS, C.J. & NESER, S. 1991. Biological control of *Lantana camara* (Verbenaceae) in South Africa. *Agriculture, Ecosystems and Environment* **37**: 57–75.

GORDON, A.J. & KLUGE, R.L. 1991. Biological control of St. John's Wort, *Hypericum perforatum* (Clusiaceae), in South Africa. *Agriculture, Ecosystems and Environment* **37**: 77–90.

HARLEY, K.L.S. & FORNO, I.W. 1992. *Biological Control of Weeds.* Inkata Press, Melbourne.

HENDERSON, L. 1989. Invasive alien woody plants of Natal and the north-eastern Orange Free State. *Bothalia* **19**: 237–261.

HENDERSON, L. 1991a. Invasive alien woody plants of the Orange Free State. *Bothalia* **21**: 73–89.

HENDERSON, L. 1991b. Invasive alien woody plants of the northern Cape. *Bothalia* **21**: 177–189.

HENDERSON, L. 1992. Invasive alien woody plants of the eastern Cape. *Bothalia* **22**: 119–143.

HENDERSON, L. 1995. *Plant Invaders of Southern Africa.* Plant Protection Research Institute Handbook No. 5, Agricultural Research Council, Pretoria.

HENDERSON, L. 1998a. Invasive alien woody plants of the southern and south-western Cape region, South Africa. *Bothalia* **28**: 91–112.

HENDERSON, L. 1998b. Southern African Plant Invaders Atlas (SAPIA). *Applied Plant Science* **12**: 31–32.

HENDERSON, L. & MUSIL, K.J. 1984. Exotic woody plant invaders of the Transvaal. *Bothalia* **15**: 297–313.

HILL, M.P. 1999. Biological control of red water fern, *Azolla filiculoides* Lamarck (Pteridophyta: Azollaceae), in South Africa. *African Entomology Memoir* No. 1, this issue.

HOSKING, J.R., MCFADYEN, R.E. & MURRAY, N.D. 1988. Distribution and biological control of cactus species in eastern Australia. *Plant Protection Quarterly* **3**: 115–123.

JACOT GUILLARMOD, A. 1978. Some water weeds of the Eastern Cape Province – IV. *Azolla. Eastern Cape Naturalist* **63**: 16–18.

JULIEN, M.H. & GRIFFITHS, M.W. 1998. *Biological Control of Weeds: A World Catalogue of Agents and their Target Weeds.* 4th Edition. CABI Publishing, U.K.

NESER, S. & KLUGE, R.L. 1986. The importance of seed-attacking insects in the biological control of alien invasive plants. In: MacDonald, I.A.W., Kruger, F.J. & Ferrar, A.A. (Eds) *The Ecology and Management of Biological Invasions in Southern Africa.* 285–294. Oxford University Press, Cape Town.

VOLCHANSKY, C.R., HOFFMANN, J.H. & ZIMMERMANN, H.G. 1999. Host-plant affinities of two biotypes of *Dactylopius opuntiae* (Homoptera: Dactylopiidae): enhanced prospects for biological control of *Opuntia stricta* (Cactaceae) in South Africa. *Journal of Applied Ecology:* in press.

WELLS, M.J., DUGGAN, K.J. & HENDERSON, L. 1980. Woody plant invaders of the central Transvaal. *Proceedings of the Third National Weeds Conference of South Africa.* 11–23. Balkema, Cape Town.