Discovery of an alien invasive, predatory insect in South Africa: the multicoloured Asian ladybird beetle, *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae)

Riaan Stals[a*] **and Goddy Prinsloo**[b]

THE ASIAN LADYBIRD BEETLE, *HARMONIA axyridis* (HA) (Insecta: Coleoptera: Coccinellidae), is a generalist predator long valued as a biocontrol agent of pestiferous aphids and other invertebrates. However, HA has become highly invasive in North America and Europe. The beetle is eurytopic, broadly polyphagous, very dispersive and phenotypically highly plastic. In the United States and Europe, this pest is implicated in adverse ecological impacts involving changes in invaded communities through interspecific competition and intraguild predation. Additionally, HA can be a household nuisance, and affect human health and agricultural production. The beetle has now reached South Africa. A founder population has become established in the Western Cape province, and the species has also been collected in the Eastern Cape province. We present illustrated diagnoses of HA and selected resident South African Coccinellidae with which it may be confused. There is reason to suspect that HA will spread rapidly through much of South Africa and beyond and bring to bear its negative consequences here. The early detection of this incursion presents a rare opportunity to study an anticipated biological invasion virtually from its beginning.

Introduction

Invasions of ecosystems by non-native organisms are accelerating due to a burgeoning human population and rising, rapid human movement and the global transportation of goods.[1,2] Little is known about the vast number of species that have spread throughout the world, intentionally or inadvertently introduced to new areas by humankind.[1,3] One such species is the multicoloured Asian ladybird beetle, or harlequin ladybird beetle, *Harmonia axyridis* (Pallas, 1773) (Coleoptera: Coccinellidae). *Harmonia axyridis* (HA) exemplifies what has somewhat brazenly been termed the 'Achilles' heel of classical biological control', namely, non-target effects.[4–7] HA is valued and exploited because it preys voraciously on diverse pestiferous aphids and other soft-bodied arthropod pests on various cultivated crops.[6–9] Recently, it began 'changing' its spots to emerge as a potentially invasive and harmful organism.[6,7,9,10]

The main aim of this paper is to record the presence and apparent establishment of the beetle in South Africa. To facilitate its recognition, we present a brief description and photographs of HA and compare it to resident Coccinellidae with which it may be confused. Initial field observations in South Africa are outlined, and the principal features of the invasiveness of HA as observed in the northern hemisphere are summarized. We consider future studies of the insect in South Africa to be imperative.

The voluminous literature on HA has been reviewed three times in the recent past.[6,7,9] More generally, the use of predatory Coccinellidae in classical biological control has also recently been reviewed at least three times.[10–12] In even broader terms, the ecological effects of invasive arthropod generalist predators, including HA and other Coccinellidae, were reviewed most recently by Snyder and Evans.[13] Avoiding undue repetition, we refer the reader to these reviews and their substantial reference lists. Recurrent both in these reviews and in the pertinent primary literature is a polarization of opinions: in strict terms, whether HA is a valuable biocontrol agent or a pest; and, more broadly, whether generalist predators are at all suitable in classical biological control of invertebrate pests, or not. Participation in these debates is beyond the scope of the present paper.

Discovery of *Harmonia axyridis* in South Africa

The non-native ladybird beetle *Harmonia axyridis* apparently has become established in South Africa. In mid-October 2006, on the Tygerhoek Experimental Farm (34°09′12″S, 19°54′15″E), Riviersonderend, Western Cape province, adults and larvae of an unfamiliar ladybird beetle species were collected from wheat. These beetles attracted attention as both larvae and adults were numerous and were clearly efficient predators of all the aphid species on wheat at the time. The beetles were positively identified as HA at the South African National Collection of Insects (SANC), Pretoria. Voucher specimens have been deposited in the SANC, the Transvaal Museum (TMSA), Pretoria, and the Iziko South African Museum (SAMC), Cape Town.

This species was previously observed, but not collected, at Tygerhoek in September/October 2004, when fairly large numbers of aphids were present on wheat. They were not detected during 2005, when aphid infestations were very low. In October 2006, adults, larvae and eggs (field-collected and positively associated through laboratory rearing) were found. Copulation was observed in the field. From these observations combined we infer that a population of HA has established and is reproducing at Tygerhoek. In November 2006, large numbers of HA were encountered on durum wheat at Tygerhoek. Incidental observation did not reveal the beetle on plants other than cereals. HA individuals were observed intermingling freely with another aphidophagous ladybird beetle, the naturalized *Hippodamia* (*Adonia*) *variegata* (Goeze).

In March 2007, the SANC identification service received HA specimens collected in the Eastern Cape province, in *Capisicum* plantations on two farms in the Bellmont Valley, about 10 km east of Grahamstown. This is more than 600 km east of Tygerhoek. On Varnam Farm (33°19′30″S, 26°38′05″E), HA were captured in November 2005, October 2006 and March 2007, and on Lower Melrose Farm (33°19′45″S, 26°38′40″E), in May 2006 (C. Hepburn, pers. comm.).

Upon enquiry among coccinellid experts worldwide, it came to light that at least one HA specimen had been collected in South Africa previously (H. Fürsch and M. Uhlig, pers. comms). This specimen, deposited in the Natural History Museum of the Humboldt University, Berlin, Germany, was collected in December 2002, 30 km NW of Swellendam, Western Cape (33°54′S, 20°11′E), which is *c.* 40 km NW of Tygerhoek. The substantial collections of both identified and unidentified Coccinellidae in the SANC and the TMSA were scoured for additional specimens of HA, but none was found. The SAMC holds no specimens of HA identified as such (M. Cochrane, pers. comm.), but we

[a]National Collection of Insects, ARC-Plant Protection Research Institute, Private Bag X134, Queenswood, Pretoria 0121, South Africa.
[b]Plant Protection Division, ARC-Small Grain Institute, Private Bag X29, Bethlehem 9700, South Africa.
*Author for correspondence. E-mail: stalsr@arc.agric.za

have not yet had the opportunity to study the unidentified Coccinellidae there.

This is the first report of HA being present in the field in South Africa. Currently, we do not know whether the beetle is restricted to the aforementioned localities or whether it is more widespread. Incidental observation in October 2006 near Caledon (*c.* 34°12′S, 19°20′E), about 60 km WSW of Tygerhoek, failed to reveal HA. Also unknown is how long HA has been in South Africa, how it gained entry to the country, and whence it originated. Our confirmation of HA's presence in South Africa is of considerable concern, given its potentially aggressive and invasive nature, as is presently being evaluated and documented in North America and Europe.[6,8,14–24]

Identity, prey and geographical distribution of *Harmonia axyridis*

Harmonia axyridis is a 'typical' member of the beetle family Coccinellidae, subfamily Coccinellinae, tribe Coccinellini. It is primarily an arboreal species, but in its expanded range common also in an array of field crops.[6,7] As are all Coccinellinae, HA is predatory, and, as is typical for the Coccinellini, aphids (Hemiptera: Sternorrhyncha: Aphididae) are the essential prey of both adults and larvae.[11,25] HA is, however, not solely aphidophagous, but is a generalist predator. It can develop on foods with very different biochemical composition.[26] The beetle has been recorded feeding on various other Sternorrhyncha, Acari, eggs of Chrysopidae (Neuroptera), Lepidoptera eggs and larvae, and immature stages of Coleoptera (significantly including other coccinellid species), and on pollen and fruit.[6,7,9] Cannibalism among HA is common.[6,7,9,11,27]

The presumed origin of HA is central and eastern Asia.[7,28] Since 1916, it was released several times as a biocontrol agent in the United States,[7,29] but the first establishment there was observed only in 1988.[28] Whether this establishment resulted from purposeful release or accidental introduction is contested.[16,29,30] After establishment, HA spread rapidly across North America and is currently present in most of the contiguous United States[7] and southern Canada.[31] Since 1982, HA has been deliberately released in mainland Europe,[7,8] where feral populations have since developed widely in cities and natural habitats.[6,8] HA was never deliberately introduced into the United Kingdom, but it reached Britain in 2004, apparently by multiple routes.[32] In 2002, it was first reported from Brazil, also apparently not deliberately introduced.[33]

Figs 1–6. Dorsal views of the alien ladybird beetle species *Harmonia axyridis* (Pallas) and some resident South African Coccinellidae with which it may be confused. **1**, *H. axyridis*, fully spotted colour form. **2**, *H. axyridis*, virtually spotless colour form. **3**, *Cheilomenes lunata* (Fabricius), yellow colour form. **4**, *Harmonia vigintiduosignata* (Mulsant), spotted colour form. **5**, *Hippodamia* (*Adonia*) *variegata* (Goeze), nine-spotted colour form. **6**, *Henosepilachna bifasciata* (Fabricius). Scale bars = 1 mm. Arrows on Figs 1, 2: top arrows: the yellowish-white oval areas at the sides of the pronotum; bottom arrows: the transverse ridges above the elytral apices.

Appearance and recognition of *Harmonia axyridis*

The following brief descriptions of the adults and late-instar larvae of HA are based on those of Koch[7] and of Gordon and Vandenberg.[34]

Adult HA (Figs 1, 2) are 4.9–8.2 mm long and 4.0–6.6 mm wide. The body is strongly convex, subcircular in outline, glossy and hairless. Dorsal colouration and markings are highly variable. The pronotum bears black central markings of up to five spots, two curved lines, frequently an M-shaped mark, or a solid trapezoid. The lateral surfaces of the pronotum bear yellowish-white oval areas (top arrows on Figs 1, 2). The elytral ground colour ranges from yellow through orange to red, with zero to 19 black spots, or the elytra can be black with two or four large orange or red spots. A transverse ridge is usually present above the elytral apices (bottom arrows on Figs 1, 2).

Although environmental factors play a role, HA's remarkable colour polymorphism has a genetic basis,[6,7] which invokes the possibility of founder effects and spatial partitioning of colour forms. Whereas the dark colour forms are common in Asia, they are rare and localized in North America, but present in Britain.[6,7,15,16] All HA specimens recovered in South Africa to date have a pumpkin-yellow to orange ground colour and display the gamut of spottiness or spottilessness (Figs 1, 2). No black specimens have yet been found in South Africa.

Two species of the genus *Harmonia* Mulsant are native to South Africa, namely *H. vigintiduosignata* (Mulsant) and *H. pardalina* (Gerstaecker). The appearance of the former (Fig. 4) is also highly variable, and it primarily inhabits the eastern, mesic regions of South Africa. *Harmonia pardalina* is scarce in local collections, and occurs from the Limpopo province northwards.

HA adults are readily discernible from all other southern African ladybird beetles. Confident field identification is possible taking into account the aforementioned combination of size, shape, lack of pilosity, and colour pattern (albeit variable). The most diagnostic colour characteristic is the yellowish-white 'ears', twin oval markings at the sides of the pronotum that are virtually always present (top arrows on Figs 1, 2). Principal disqualifying characteristics of possible 'look-alikes' are given below. Measurements given below are the lengths of the smallest and the largest conspecific individuals in the SANC.

Truncated elimination key to native and resident coccinellid species similar to HA

- If any longitudinal or wavy lines are present on elytra (e.g. Fig. 3) — **not HA**. (The common species *Cheilomenes lunata* (Fabricius) (Fig. 3) is similar to

HA in size and shape, but its pattern consists of yellow to red flecks on a black background.)

- If pattern of spots is more or less as in Fig. 4, then specimen would be larger than HA (length *c.* 8.5–10.2 mm) — **not HA**; possibly *Harmonia vigintiduosignata* (Fig. 4).
- If pattern of spots is more or less as in Fig. 5, then specimen would not be strongly convex and would be smaller than (most) HA (length *c.* 4.5– 5.0 mm) — **not HA**; probably *Hippodamia* (*Adonia*) *variegata* (Fig. 5).
- If body is covered with fine hairs it would not appear glossy (e.g. Fig. 6), and arrangement of spots would be different from that of HA — **not HA**; subfamily Epilachninae (Fig. 6).
- If elytra are predominantly shiny black, with or without yellow or red spots, and size is similar to that of HA, then outline of body would not be uninterruptedly subcircular, and the sides of the pronotum would be black or bright yellow, never yellowish-white as in Figs 1, 2 — **not HA**; possibly subfamily Chilocorinae.

There are four larval instars, the fourth being 7.5–10.7 mm long (Fig. 7). It is larger and more robust than larvae of most resident South African coccinellids, with conspicuous dorsal outgrowths and long legs. The ground colour is blackish, and the dorsal areas of some of the abdominal segments have orange markings which increase in number and extent with each successive moult (Fig. 7).

Adverse features of *Harmonia axyridis*

The arrival in any biotic community of a 'new' coccinellid may significantly affect established guilds of predatory arthropods.[13,18,35] Moreover, the complex trophic roles of generalist predators like HA may lead to widespread and varied impacts throughout the invaded community.[13] Since HA is eurytopic, polyphagous and has a high degree of phenotypic plasticity, it may spread easily and become implicated in exploitative and interference competition with local Coccinellidae and other predators, including intraguild predation (IGP).[6,7,9,13,18,35–37] In North America and elsewhere, it has been demonstrated repeatedly that both IGP and competitive advantages are asymmetric in the favour of HA.[6,17,23,27,37] Changes in the composition and dynamics of the predatory arthropod guild may also weaken or, paradoxically, strengthen herbivore suppression, and may interfere with biological control programmes.[9,13,18]

Fig. 7. Late-instar larva of *Harmonia axyridis* on wheat, postero-dorsal view.

HA has some bizarre effects on humankind directly. Large overwintering aggregations on or in buildings in North America and Europe are a major household nuisance.[7,8] Handling of HA may elicit reflex bleeding, leading to possible stains on walls and fabric.[6] Indoors, HA allergens are the agent of an emerging hypersensitivity-allergy syndrome among humans.[38–40] Injury upon insult, HA can—surprisingly—afflict humans with a severe bite.[7,41]

HA will feed opportunistically on (damaged) fruit when prey is scarce.[7,9,24] HA individuals present among grapes crushed for wine production may taint the vintage with odours of rancid peanut butter, rotting spinach, blue cheese or sawdust.[21] In 2003, over a million litres of HA-tainted wine had to be destroyed in Ontario, Canada.[21] In the US, HA has become a nuisance pest also in bee-keeping.[14]

Potential impacts and future efforts in South Africa

Ladybird beetles have impressive dispersal abilities.[42] After establishment, HA spread rapidly across North America, to become the commonest aphidophagous coccinellid in many regions.[7,16,36] It established quickly in mainland western Europe and is increasing its range and abundance there.[6,8,9] Majerus *et al.*[6] predicted that HA will spread across the entire British mainland by 2008, after arrival in 2004. Koch *et al.*[43] concluded that the invasion of HA over broad areas in South America is possible. In all likelihood, HA will spread rapidly across most of South Africa and beyond and eventually exert the adverse impacts outlined above. Ecological modelling would provide information on the dispersive potential of HA in Africa.

An awareness campaign of the presence of HA in South Africa is recommended and can be coupled to an initial monitoring scheme involving the popular press and citizen science. Formal study of HA in South Africa is imperative, and concurrent studies of resident southern African Coccinellidae may prove rewarding. Whereas the local coccinellid fauna is reasonably well known taxonomically, its ecology is inadequately studied.

The early detection of HA in South Africa presents the rare opportunity to study an anticipated biological invasion virtually from its beginning. There is also the prospect of comparing the invasion biology of HA in South Africa and the northern hemisphere.

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