REVIEW ARTICLE

A taxonomic review of white grubs and leaf chafers (Coleoptera: Scarabaeidae: Melolonthinae) recorded from forestry and agricultural crops in Sub-Saharan Africa

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Abstract

Integrated Pest Management (IPM) is difficult to implement when one knows little about the pest complex or species causing the damage in an agricultural system. To implement IPM on Sub-Saharan African melolonthine pests access to taxon specific knowledge (their identity) and what is known (their biology) of potential pest species is a crucial step. What is known about Sub-Saharan Africa melolonthine white grubs and chafers has not yet been amalgamated, and this review thus synthesizes all available literature for the Region. The comprehensive nature of the review highlights pest taxon trends within African melolonthines. To facilitate the retrieval of this information for IPM purposes, all relevant taxonomic and biological information is provided for the taxa covered including an on-line supplementary annotated-checklist of taxon, crop, locality and reference(s). Based on the literature reviewed, recommendations are made to promote effective and efficient management of African melolonthine scarab pests. An on-line supplementary appendix provides a list of specialists, useful internet resources, keys, catalogues and sampling methods for the larvae and adults of melolonthine scarab beetles for subsequent morphological or molecular work.

Keywords: Africa, southern Africa, Scarabaeidae, Melolonthinae, White Grubs, Chafers, Scarab Pests, Larvae, Agriculture, Identification, Taxonomy.

Introduction

This review aims to provide a checklist of the species of Sub-Saharan African Melolonthinae that have been recorded as pests in agricultural and forestry crops (Table 1 supplementary material),

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and draws attention to groups most in need of revision from a pest management perspective. Additionally, it provides comprehensive review and bibliography of all traced literature (especially taxonomic) specific to the melolonthine white grubs and chafers of the Region. It is hoped that this will facilitate white grub research in Sub-Saharan Africa via enhanced access to information, and the reduction of duplicated research efforts. Based on this synthesis, recommendations relevant to white grub and chafer taxonomy in Sub-Saharan Africa are proposed. To constrain the size and scope of the review, it covers only the subfamily Melolonthinae, with the remaining scarab subfamilies that contain species of economic concern being dealt with in forthcoming studies.

The larvae (white grubs) and adults (chafers) of five subfamilies of Scarabaeidae (Aphodiinae, Dynastinae, Cetoniinae, Melolonthinae and Rutelinae) include species that feed on the roots, stems, fruit or foliage of many crops, and therefore may be sporadic forestry and agricultural pests (Table 1 supplementary material). Colloquially these larvae are known as white grubs, cane grubs or curl grubs when they damage agricultural crops in different regions of the World. White grubs are readily identified by their 'C-shaped' bodies and sclerotized head capsules, while the more variable adults generally have an ovoid body shape and lamellate antennae (Richter, 1958, 1966). Related scarab families, for example dung beetles (Scarabaeinae), have similar larvae, but as these groups are beneficial recyclers, they are generally not referred to as white grubs.

Melolonthine scarab beetles have a complete life-cycle (holometabolous); a fertilized female lays eggs, these hatch into the first of three larval stages or instars, the final (or third) instar enters a pre-pupal stage before pupation, from which adults emerge when environmental conditions are conducive (Ritcher, 1958, 1966). The duration of the larval stage can vary from one to three years depending on the environmental conditions and species' life cycle (Ratcliffe, 1991). However, species with two to three year life-cycles often have adults active each year due to an overlapping of generations. The phenology of the adults is unknown for most species, but based on adult phenological data compiled from museum records for *Asthenopholis* (Harrison, 2009) and *Pegylis* (Harrison, 2014b), adults from these genera are present in varying numbers throughout summer each year.

Species distributions are dependent on a variety of factors. Some white grubs have a narrow distribution (stenotopic, e.g., *Asthenopholis subfasciata* (Harrison, 2009) and *Macrophylla* spp.) while others have a wider distribution (eurytopic, e.g., *Pegylis sommeri* (Harrison, 2014b)). Soil type, texture and moisture content can play an important role in the distribution of certain white grub species (Allsopp, *et al.,* 1992; Cherry & Allsopp, 1991; Logan, 1997). Females of some white grub species are flightless, e.g., *Macrophylla pubens* (Fenwick, 1947; Omer-Cooper, *et al.,* 1941, 1941-1942, 1948), and this has implications for control strategies and the geographic extent of an outbreak. The adult activity period can be quite narrow (just a few days after rain) for some species of chafer (Harrison, pers. obs.) or extend over a longer time period, i.e., weeks and months for *Pegylis sommeri* (see phenology figs in Harrison (2014b)).

Pest status of scarabs

In large numbers the feeding activity of white grubs and chafers in crops reduces yields and facilitates secondary microbial infections through the damaged plant cuticle (Smith, *et al.,* 1995; Miller, *et al.,* 1999). For example, in southern Africa, white grubs have been recorded as sporadic subterranean pests on tree-seedlings, sorghum, sugarcane, pineapples, potatoes and turf grass (see Table 1 supplementary material for a complete list). Additionally, the adult chafers are often defoliators (e.g. *Pegylis* spp.) in forest plantations, fruit orchards, vineyards and rose gardens (Table 1 supplementary material). At least 50 different species of commercially grown plants have records of Melolonthinae being destructive to parts of these plants (Table 1 supplementary material).

Introduced alien species

Most, if not all, African melolonthine scarab pests are endemic to parts of Africa, and no introduced scarab pest species are recorded for South Africa (Picker & Griffiths, 2011). However, as this is a broad and general information source, it by no means rules out the possibility of there being alien scarabs in Sub-Saharan Africa. A possible exception is *Phyllophaga smithi* (Arrow, 1912), which was originally described as *Phytalus smithi* from the Caribbean (Barbados & Trinidad) and introduced into Mauritius (Evans, 2003). This species was recorded (Macdonald, *et al.,* 2003: 74) from Tanzania and mentioned as a sorghum stem-borer in eastern Ethiopia (Tefera, 2004). However, there is no published confirmation of this introduction in the primary literature for sugarcane pests known from Tanzania, but the African endemic *Cochliotis melolonthoides* is well established as a sugarcane pest in Tanzania (Jepson, 1956; Carnegie, 1974a, b). Consequently, the Macdonald *et al.* (2003) and Tefera (2004) records of *P. smithi* occurring on the African mainland may be based on the exotics being confused with an African species of *Schizonycha*, which is quite similar to *Phyllophaga* (= *Phytalus*) Arrow (1912).

Conservation of localized endemic species

Localized endemics are of particular conservation importance. For example, *Asthenopholis subfasciata* can become an important sporadic pest of pineapples in the Eastern Cape of South Africa (Petty, 1976, 1977a,b, 1978, 1982, 1990, 1994, 2001, Petty, *et al.,* 2002). However, it is endemic to South Africa and is also one of only seven known species of *Asthenopholis* (Harrison, 2009). As a localized endemic and part of the country's biodiversity, we need to control it responsibly when it reaches localized pest levels. Another example of a localized endemic that can become a sporadic pest species is *Pseudachloa leonina* on golf greens near Pretoria, South Africa (pers. comm. At Schoeman 2005).

Access to information

Fragmentary, unsynthesized information relating to scarabs as pests in African crops reduces the efficiency of research on economically important species. For example, the paucity of information on *Eucamenta eugeniae,* originally described as a pest of clove (*Eugenia caryophyllata*) from Zanzibar (Arrow, 1932; Andre Moutia, 1941). But a recent paper (Conlong & Mugalula, 2003) omitted these early publications and reported *E. eugeniae* only as a new pest of sugarcane in Uganda.

Information relating to the same insect taxon, but disguised due to an incorrect identification is another problem. For example, the incorrect identification of *Pegylis sommeri* (previously *Hypopholis*) as *Macrophylla ciliata* (Herbst) as a pest of pineapple in South Africa (Petty, 1976, 1977b, 1978, 1990, 2001; Petty, *et al.,* 2002) resulted in the redescription of the larvae of *P. sommeri* (Smith, *et al.,* 1995), which had previously been described (Prins, 1965). Misidentification resulted in a duplication of effort, lack of efficient control strategies, crop destruction, and reduced economic benefits.

The importance of having named pests

The success of an Integrated Pest Management (IPM) program for melolonthine white grubs depends strongly on accurate identification of larvae and adults (Danks, 1988). Species level identification is important because life cycles of white grub species vary from one to three years and susceptibility to insecticides varies for species (as demonstrated in Australian cane grubs; Allsopp, *et al.,* 1995). Correct diagnosis relies upon available taxonomic expertise, published research, trained systematists, and access to museum specimens, voucher specimens and type material. In contrast to more developed countries (e.g. the United States, Australia and New Zealand) southern Africa in our view lags behind by a number of years in scarab taxonomic research on melolonthine white grub identification and research.

In a discussion on white grub identification (Omer-Cooper, *et al.,* 1941; Omer-Cooper, *et al.,* 1941-1942) the authors state that, "... *very little work has been done on these insects in South Africa, and with the present state of our knowledge we would not be prepared to say in all cases which are pests and which are not*". Later (Sweeney, 1967) added that "*Few published papers deal with the morphology and taxonomy of larval Scarabaeoidea in southern Africa, and the larvae of many species are undescribed*". However, recent taxonomic work by Ahrens (2007a,b), Conlong & Mugalula (2003), Dittrich-Schröder *et al.* (2009), Goble *et al.* (2012) and Harrison (2004, 2009, 2014a,b, this review) is a positive advancement in melolonthine research in the Region.

Morphological identification of melolonthine larvae and adults

To morphologically describe a scarab larva, the chitinous head capsule is softened in lactic acid or a weak solution of KOH and disarticulated from points of natural articulation of structures (Dittrich-Schröder, *et al.,* 2009). Ritcher (1966) provided numerous illustrations and descriptions of disarticulated scarab head capsules. This requires association of the larva with a named adult and formal description in a published paper. African melolonthines in which larvae have been described and illustrated (Table 2 supplementary material), include a small percentage of the known melolonthine diversity.

Adult identification also relies on the beetle species having been described in a validly published paper. Insect drawers of African Melolonthinae sorted only to subfamily in museum collections are testament to the lack of taxonomists dealing with this diverse group of beetles. Consequently, in many cases one can at best identify a pest melolonthine to genus level only, and even here good taxonomic keys for generic diagnoses (e.g. Péringuey, 1904; Lacroix, 2010) are the exception rather than the rule.

An ideal scenario would be as follows: a taxonomist is presented with larvae and adults of *Pegylis sommeri* and asked to identify these. In this particular instance, the larvae could be identified using Prins (1965) and the adults using Harrison (2014b). Adult specimens of *Asthenopholis* can be identified using Harrison (2009), but the larva of only one species of this genus has been described, i.e., *A. subfasciata* in Smith *et al.* (1995), leaving the larvae of the remaining six species unassociated with their adults via the taxonomic literature.

Molecular diagnostic techniques

A frequently encountered problem with white grub outbreaks is determining the white grub species. Identification is especially important because control action must be immediate to prevent further losses. Molecular DNA barcoding techniques allow for the DNA of grubs or adults to be matched with DNA sequence data (e.g. archived Genbank sequences) and possible retrieval of an identification based on these data. Once a match is retrieved the morphology of the grubs can be described in order to facilitate accurate and efficient identification in the future. This process can be used to develop identification tools. For example, Dittrich-Schröder *et al*. (2009) compiled an identification key to the scarab beetle larvae attacking sugarcane in South Africa. Using molecular methods and associating grubs with adults, tools for identification of chafers were developed for use on the Nepalese fauna (Ahrens, *et al.,* 2007a,b). This research is best done by a collaborating team of molecular biologists, beetle taxonomists and crop specialists.

Integrated Pest Management (IPM) options for white grubs and chafers

IPM of white grubs and chafers is a review topic of its own, and consequently only brief mention is included here. Control options include various forms of chemical control, cultural methods, parasitic Diptera (flies), Hymenoptera (wasps), fungi, and tillage methods. Smit (1964), Annecke & Moran (1982) and Visser (2005, 2009) provide general coverage of IPM methods relevant to the African context for many of the taxa included in this review.

Taxonomic review of the Melolonthinae with published records of significance to Sub-Saharan African forestry and agricultural crops

The world melolonthine fauna is presently divided into 28 extant tribes and 12 subtribes (Smith, 2006), of which six tribes and nine subtribes are known to occur on the African mainland. Sub-Saharan Africa includes taxa from six tribes and six subtribes as presented below. All known Sub-Saharan African Melolonthinae recorded in the literature as having the potential to become sporadic pests in agricultural and forestry crops are reviewed (Table 1). Included in Table 1 are taxonomic details (generic and specific description dates and authors) and thus this information is not repeated in the text. However, taxa not included in the checklist (Table 1) are referred to in the text including their author and publication date.

Also summarized are melolonthine species, crop attacked, life stage involved, country of origin and the source reference (Table 1 supplementary material). Thus, if not specifically mentioned below, the life stage, larva or adult, involved in the damage is included in Table 1 supplementary material.

1. Tribe ABLABERINI Blanchard, 1850

For garden flowers, Annecke & Moran (1982) list adults of *Ablabera pellucida* as feeding on carnations. Adults of *Camenta innocua* appears to occur in most major centers in South Africa (JduGH pers. obs.) and can be found at night feeding on a variety of garden plants, with roses, being one of those most seriously damaged (JduGH pers. obs.). The larvae of what was possibly *C. innocua* caused significant damage to raspberry seedlings in the George and Hermanus areas of South Africa (pers. comm. Tim Sobey Nov. 2012). Oberholzer (1959a,b) described the third instar larvae of *C. innocua* from specimens collected in Johannesburg, South Africa, but he did not indicate any pest status for the species.

In the interests of taxonomic stability, Ahrens (2007a) designated types for various African genera in the Ablaberini, including *Ablabera* Dejean, 1833; *Eucamenta* Péringuey, 1904; *Hybocamenta* Brenske, 1898; and *Paracamenta* Péringuey, 1904. Neither *Ablabera* nor *Camenta* have been recently revised, making species level identification in these genera difficult or impossible, especially bearing in mind the large number of undescribed taxa within the Ablaberini. The syntype of *C. innocua* is a single female (pers. comm. Dirk Ahrens), making the unequivocal identity of this species currently impossible in the absence of the male genitalia necessary for identification.

2. Tribe DIPLOTAXINI Kirby, 1837

Peacock (1913), looking at insect pests of cacao or cocoa bean (*Theobroma cacao* L.) in southern Nigeria, recorded *Apogonia nitidula* together with various other scarabs, but included these in a list of taxa with doubtful significance (associated with the crop but not showing signs of being an actual pest). Lepesme & Paulian (1944) recorded the same species on *Coffea robusta* in Gabon, but they provided no further details about the association. In work applying to species from neighbouring South Asia Islam *et al*. (1984) included species of *Apogonia* among the insect pests associated with green gram (*Vigna radiata* L.) from Bangladesh, India. Of the beetles studied by Islam *et al*. (1984), *Apogonia* were responsible for consuming the largest leaf area.

Bezděk (2004a) provided a catalogue of Diplotaxini of the Old World and a detailed revision on the African monotypic genus *Ceratogonia* Kolbe, 1899 (Bezděk, 2004b). He provided synonymic notes for *Apogonia cupreoviridis* Kolbe, 1886 and *A. nigroolivacea* Heyden, 1886 (Bezděk, 2008), and notes on the synonymy and geographic distribution of *Apogonia niponica* Lewis, 1895 (Bezděk, 2009). Lacroix (2008a,b) described new genera and species of Diplotaxini, and Lacroix & Bezděk (2009) proposed replacement names for *Metagonia* Kolbe, 1899 (nec Simon, 1893).

3. Tribe HOPLIINI Latreille, 1829

In South Africa, these beetles are colloquially referred to as monkey beetles (Picker & Midgley 1996). Smit (1964) recorded adult Hopliini burrowing into garden Compositae (Asteraceae), especially marigolds in Pretoria, South Africa. Prins (1965) listed *Monochelus calcaratus*, which he refered to as the small wattle chafer, as a wattle defoliator. Prins (1965) also described its larva, the only description of an African Hopliini larva (known to us). For garden flowers, Annecke & Moran (1982) recorded *Eriesthis stigmatica* and *Heterochelus connatus* feeding on carnations, and *E. vestita* feeding on dahlias. Swain & Prinsloo (1986) list species of *Heterochelus* feeding on *Acacia mearnsii,* and *Monochelus calceratus* feeding on *Acacia decurrens, A. mearnsii* and *A. melanoxylon.* Gess (1968), Myburgh *et al*. (1973, 1974), Myburgh & Rust (1975) and Coetzee & Giliomee (1985) investigated insects associated with *Protea* flowers as both pests damaging the flowers and insects likely to be exported with flowers due to their biological associations with the *Protea*. Myburgh & Rust (1975) provided a list of 34 ‘free-living pests in protea flower-heads’, including the following monkey beetles: *Anisonyx nasuus*, *Heterochelus rufimanus*, and a species of *Platychelus*. Coetzee & Giliomee (1985), in a study specific to *Protea repens* (L.), listed adult *Diaplochelus longipes* as a floral visitor. Dombrow (2006b) described two new species of *Diaplochelus* sent abroad with consignments of exported *Protea* from South Africa to Poland and the USA.

Due to the charismatic morphological diversity of the southern African Hopliini, this tribe has received greater taxonomic attention than any other in the Region. Dombrow, in particular, has revised many of the southern African genera (a list of his known papers is provided). These papers included taxonomic revisions of *Eriesthis* (Dombrow, 1997c, 2002b), *Heterochelus* (Dombrow, 2001c) and *Diaplochelus* (Dombrow, 2006b). Schein (1958) studied South African *Heterochelus* and his paper included a key (pp. 256-257) to the genera and subgenera of Heterochelina (= Hopliina).

3a. Subtribe HOPLIINA Latreille, 1829

Swain & Prinsloo (1986) included adults of *Hoplia sordita* as feeding on *Acacia mearnsii*. We are not aware of any other references relating to the biology or pest status of *Hoplia* species in Sub-Saharan Africa, but there is extensive literature on the non-African *Hoplia.* For example, Ansari *et al*. (2008) examined the susceptibility of *Hoplia philanthus* (Füessly) larvae and pupae to entomopathogenic nematodes in Belgium, while Zhang *et al*. (2011) examined the attractive responses of *Hoplia spectabilis* Medvedev to un-baited yellow or white cross-pane funnel traps in China.

4. Tribe PACHYDEMINI Burmeister, 1855

Omer-Cooper *et al*. (1941) noted that southern Africa turf (golf courses) is a human-made habitat often composed of the indigenous grass (*Cynodon dactylon* Pers.), and thus its pests are endemic, opportunistically making use of an abundant food resource. The damage caused by white grubs when they feed on grass roots, completely ‘scalps’ the roots and can result in death of the grass, especially following a dry period. Larvae of species of *Macrophylla* are potential pests of golf greens in the Eastern Cape of South Africa (Omer-Cooper, *et al.,* 1941).

Omer-Cooper *et al*. (1941, 1941-1942, 1948) provided notes on the biology of species of *Macrophylla*, where the females of at least some of the species appear to be flightless. Fenwick (1947) redescribed the male of *M. pubens* and provided the first description of its flightless female based on specimens collected on the Humewood Golf Green near Port Elizabeth, South Africa. Schoeman (1996) recorded that white grubs in turfgrass are "*usually patchily distributed, unpredictable and capable of doing severe damage before they are detected*". Due to the incorrect identification of *Hypopholis sommeri* (now *Pegylis sommeri*) as *Macrophylla ciliata* and published as *M. ciliata* in Petty’s earlier papers, the larva of *M. ciliata* (but actually *P. sommeri)* was described by Smith *et al.* (1995). However, this is actually a redescription of the larva of *P. sommeri* (see Prins, 1965). Consequently, we are not aware of any descriptions of southern African Pachydemini larvae (here we exclude *Sparrmannia flava* covered by Evans (1989) and Scholtz (1988), due to the preferred placement of *Sparrmannia* in the Melolonthini).

Evans (1988a) reviewed the taxonomy and systematics of southern Africa Pachydemini and revised some genera (Evans, 1987a,b,c, 1988b). Lacroix provided descriptions of many new African Pachydemini genera and species in 14 papers (Lacroix, 1997, 1999, 2001, 2003, 2004, 2005a,b, 2006a,b,c,d, 2008e, 2009f, 2011a) and a catalogue (Lacroix, 2007).

5. Tribe MELOLONTHINI Leach, 1819

5a. Subtribe MELOLONTHINA Leach, 1819

Swain & Prinsloo (1986) included *Psilonychus groendahli* on *Acacia mearnsii* in a list of phytophagous insects on forest trees and shrubs in South Africa. Specimens of *Psilonychus* were collected in pheromone traps set to catch the lepidopterous pest *Helicoverpa armigera* (African Bollworm) from chicory fields in the Eastern Cape of South Africa (Midgley *et al.,* 2008, Midgley pers. comm.). There are eight described species of *Psilonychus* and Harrison (in prep.) plans to revise this genus, making its species and what we know about them accessible to other entomologists.

The adults of three *Sparrmannia* species (*S. acicularis*, *S. flava* and *S. transvaalica*) were recorded in the vicinity of pistachio nut trees in the Prieska area of the Northern Cape of South Africa by Louw (2001). However, only *S. flava* caused economic damage by defoliating trees, thereby forcing them to produce new leaves. It is suspected that this regrowth reduced the ultimate nut yield of trees (Louw, 2001). Haddad *et al*. (2005) and Haddad & Louw (2006) recorded the spider groups present in pistachio orchards in South Africa and noted their potential as biological control agents for pistachio pests. *Sparrmannia* species are caught in spiders' webs (Harrison pers. obs.) and thus one can expect that both large sedentary and orb-weaving spiders would catch and feed on *Sparrmannia* adults. Scholtz (1988) investigated the breeding biology of *S. flava* in the arid Kalahari and noted that, under desert conditions, the life cycle is one year in duration. Larvae are able to maximize feeding after rain and then become dormant until rain allows them to feed again. Quite unique for the melolonthines, or perhaps just unrecorded due to the absence of studies on African arid chafers, is the larval behaviour of foraging at night on the soil surface for antelope dung, which is then taken below the soil surface, rehydrated and fed upon by these larvae. Evans (1989) summarized what is known about the biology of *Sparrmannia*. All species appear to feed on plants as adults, but there is a lack of established host plant records, even from mass swarming observations. Of the 24 known species, two appear to be diurnal while many other species have been collected at light traps at night. Mating swarms of *S. transvaalica* have been observed at dusk, and in the morning and late afternoon (Harrison pers. obs.). Evans (1989) provided a detailed and thorough revision of the 24 known species of *Sparrmannia* and a description of the second instar larvae of *S. flava*.

5b. Subtribe SCHIZONYCHINA Burmeister, 1855

Larvae of *Entyposis impressa* were recorded by Mansfield-Aders (1920) feeding on the roots of caladiums and castor oil plants. Lacroix & Montreuil (2012) revised *Entyposis* and recognized nine species in the genus. Male *Entyposis* are unusual amongst melolonthines in that they have indented dynastine-like pronota including small pronotal horns making it easy to recognize this genus of African melolonthines.

Schmutterer (1964), in an overview of the insect pests on southern Somalian crops, noted larvae of a species of *Schizonycha* feeding on banana plant roots. Büttiker & Bünzli (1957) included *Schizonycha profuga*, *S. citima* and *Hecistopsilus molitor* in their survey of the more important leaf chafers on tobacco in Zimbabwe. Tarr (1958) examined the relationship between feeding by species of *Schizonycha* grubs on Dolichos Bean (*Dolichos lablab*) seedlings, resulting in wilt and often followed by stem blight. They discuss how various chemical seed dressings can reduce losses. In a list of phytophagous insects in South Africa, Swain & Prinsloo (1986) listed *S. fimbriata* as associated with *Acacia mearnsii*. Larvae of *S. fimbriata* caused damage to soya beans in KwaZulu-Natal (Hittersay, 2005). In the Trans Nzoia district of Kenya, changes in the intercropping practices to enhance soil nutrition resulted in an increase in the abundance of root-feeding chafer (*Schizonycha* spp.) grubs (Medvecky, *et al.,* 2006, 2007; Medvecky & Ketterings 2009). Apparently, the enhanced soil nutrition may have benefitted white grubs developing in the soil. In a review of the insect pests associated with yam production and storage, Korada *et al*. (2010) included unnamed species of *Schizonycha* larvae as boring into and feeding on the tubers during the pre-harvest period. Hajek *et al*. (2005) in their '*Catalogue of introductions of pathogens and nematodes for classical biological control of insects and mites*' listed *Paenibacillus popilliae* (Dutky) (Bacillaceae) as having been released in 1956 in Kenya for the control of *Schizonycha* spp. In this instance, *P. popilliae* was not recovered after release (Hajek, *et al.,* 2005). *Schizonycha* is the African equivalent to the diverse *Phyllophaga* Harris of the New World. Pope (1960) revised the southern African species of *Schizonycha*, and at that time recorded over 300 described species, with 292 of these being from Africa, and 120 being from southern Africa. Undoubtedly, many undescribed species remain, complicating efforts for routine identification of this important pest containing genus. Lacroix (2010) provided a World checklist of 349 species for *Schizonycha*.

5c. Subtribe PEGYLINA Lacroix, 1989

Harrison (2014a) provides a phylogeny for the Pegylina while Harrison (2014b) provides detailed coverage of the natural history, pest status, larval description, parasites and previous chemical control of South African *Pegylis* species. Lacroix (2008c, d) described new species of *Pegylis* and included all known species of *Pegylis* in his 2010 book.

5d. Subtribe LEUCOPHOLINA Burmeister, 1855

Lepesme & Paulian (1944) recorded larvae of *Afrolepis pygidialis* feeding on the roots of *Coffea excelsa* in Gabon, provided a brief description of the larvae and pupae of *A. pygidialis,* and a key to the species in the genus. Decelle (1968) proposed *Afrolepis* as a replacement name for *Oligolepis* Brenske, 1903 as the latter generic name was already occupied within the vertebrates. Lacroix (2010) provided redescriptions, a key to species, and maps for the five known species of *Afrolepis*.

Harrison (2009) provides detailed coverage of the natural history and pest status of *Asthenopholis*, revises the genus and recognizes seven species of *Asthenopholis* from these countries: South Africa (5 spp.), Lesotho (1), Swaziland (1), Kenya (1), Tanzania (2) and Uganda (1).

The larvae of *Cochliotis melolonthoides* are considered an important pest of sugarcane in Tanzania (Jepson, 1956). Lacroix (2009a) provided a revision of the four known species of *Cochliotis*, including the description of a new species from Somalia. *Cochliotis* species are known from Kenya, Tanzania and Somalia (Lacroix, 2009a). Jepson (1956) discussed the biology, larvae (including third instar head capsule and rastal pattern illustrations) and adults of *C. melolonthoides*. Additionally, Jepson (1956) included recommendations for the cultural, biological and chemical control of *C. melolonthoides* larvae, which are pests of sugarcane in Tanzania. Hajek *et al.* (2005) listed *Paenibacillus popilliae* (Dutky) (Bacillaceae) as having been released in 1968 in Tanzania for the control of *C. melolonthoides.* It is possible that *P. popilliae* became established, but the presence of an indigenous milky disease confounded conclusive results.

Taylor & Smithers (1959) recorded *Eulepida mashona* as a pest of Ley pasture in Zimbabwe. "*In ley farming, the field is alternately used for grain or other cash crops for a number of years and 'laid down to ley', i.e., left fallow, used for growing hay or used for pasture for another number of years. After that period it is again ploughed and used for cash/field crops*" (Wikipedia, 2015). Towards the end of the growing season in Zimbabwe, Wilson (1963, 1972) mentioned that larvae of *E. mashona* can damage maize plants when the cobs begin to ripen in March. In their list of phytophagous insects on forest trees and shrubs, Swain & Prinsloo (1986) included *E. mashona* as associated with *Acacia mearnsii*. Gomez (1988) included *E. mashona* in the list of '*indigenous and traditional foods in Zimbabwe*'. From an IPM perspective eating *E. mashona* would reduce high populations of this chafer and also provide rural communities with free nutrients. However, Tagwireyi *et al*. (2000) reported a case of cantharadin poisoning presumably caused by ingestion of a blister beetle (Meloidae) by a four-year-old child in Zimbabwe. The cause of the ingestion is thought to be due to mistaken identification of the edible *Eulepida mashona* with the blister beetle *Mylabris distincta* Thomas. Lacroix (2008f, 2009a,b,c,d,e, 2011b) revised various genera of Leucopholina. Lacroix (2010) covered the 26 known species of *Eulepida* (including descriptions of three new species); he also provided descriptions, keys, distribution maps and line drawings, including the male genitalia for all 26 species.

6. Tribe SERICINI Kirby, 1837

6a. Subtribe SERICINA Kirby, 1837

In Nigeria, *Pseudotrochalus concolor* is associated with the following plant species: *Bixa orellana, Citrus acida, Citrus limonia, Gossypium hirsutum, Haematoxylon campechianum, Quisqualis indica, Spondias lutea* and *Zea mais* (Golding, 1927, 1937). Certain genera of African Sericinae (Ahrens, 2007a) are currently being revised (Ahrens pers com).

6b. Subtribe TROCHALINA Brenske, 1898

In southern Nigeria, Peacock (1913) recorded several species of *Trochalus* together with other scarabs on cacao or cocoa beans (*Theobroma cacao* L.), but he placed these taxa on his list of doubtful significance (associated with the crop but not an actual pest). Hargreaves (1937) recorded *T. carinatus*, *T. gibbus* and *T. pilula* as feeding on avocado, *Cola nitida* and cotton in Sierra Leone. Swain & Prinsloo (1986) included *T. byrrhinus* and *T. fulgidus* in their list of phytophagous insects of forest trees and shrubs in South Africa for *Acacia mearnsii*.

Conclusion

Identification of melolonthine white grubs and adult chafers unlocks published information on these taxa and creates the necessary nomenclatural foundation for research into the biology and ecology of the species. This review provides a foundation for taxonomic research on this agriculturally important pest group. Research is required in all areas relating to African white grub and leaf chafers in order to improve our ability to make species level pest identifications, understand their biology, and implement IPM strategies when required. It is important to conserve these same species as they are also African endemics and an integral part of the continent's rich biodiversity. Recent work by Ahrens, Bezděk, Conlong, Dittrich-Schröder, Goble, Harrison, Lacroix and Way (see reference list) indicates a positive trend to more taxonomic and applied research being undertaken on South African and southern African scarab pests.

Recommendations

Based on this review of the literature from 1889 (Ormerod & Janson, 1889) to the present, the following recommendations can be made to improve the continuity of information relating to African scarab pest taxonomy and associated research in future. These include:

- inclusion of the following key words in paper titles / keyword lists to facilitate electronic literature searchers, i.e., ‘white grub, leaf chafer, Scarabaeidae, Melolonthinae, Africa and scarab pest’;

- clear indication of the methods used to establish larvae-to-adult conspecificity, when identifications are provided, e.g., adults bred from larvae, larvae and adults found in association with one another, or via molecular matching techniques;
- a clear statement of the person responsible (and their professional affiliation) for taxon identifications, e.g., 'Riaan Stals of the ARC-PPRI[2]'; and
- information on the national museum / research institution in which the vouchers on which the identification is based have been deposited, e.g., 'ARC-PPRI or SANC[3]'.

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