Prospects for the biological control of prickly acacia, *Acacia nilotica* (L.) Willd. ex Del. (Mimosaceae) in Australia

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Summary

Prickly acacia, *Acacia nilotica* (L.) Willd. ex Del. (Mimosaceae), a major weed of grasslands in north west Queensland, is native to Africa and the Indian subcontinent. A large and diverse list of insect species known to attack prickly acacia over this extensive region has been compiled. The host specificity and the potential of particular species as biological control agents is discussed.

Introduction

The weed problem

Prickly acacia, *Acacia nilotica* (L.) Willd. ex Del., is one of Queensland's worst weeds. It currently infests seven million hectares of the once open Mitchell grassland. Given a series of wet years it has been predicted the entire grassland ecosystem could be lost to prickly acacia thorn forest. Thorny thickets interfere with mustering and a canopy cover of 20% reduces herbage production by 50% resulting in increased soil erosion and reduced biodiversity (J. Carter personal communication). A variety of management strategies have been developed. In particular, mechanical control through double chain pulling has been successfully used to remove dense infestations in some situations (P. Jeffery personal communication). Prickly acacia is not native to Australia and hence biological control through the introduction of insects from its native range is a possible control option.

Successful attempts at biological control of woody weeds

There is a tendency for the impact of insects on a plant species' abundance to be underestimated. Wilson (1964) stated "it is highly doubtful if plant ecologists, examining without knowledge of past events the present situation of any weed that has been controlled biologically in any country, would attribute any importance to the effects of insects on the weed's abundance". Perhaps as a consequence, the likelihood of achieving successful biological control of present weeds tends to be underestimated.

There are several examples of the successful control of woody weeds using biological control agents. The tree *Cordia curassavica* (Jacquin) Roemer & Schultes (Ehretiaceae) was controlled in Mauritius with a leaf-feeding beetle, *Metrogaleruca obscura* (Degeer) in combination with a wasp which attacks developing seeds, *Eurytoma attiva* Burks (Julien 1992). A combination of introduced insects including flower-feeding, seed-feeding and wood boring insects have greatly reduced the spread of the tree *Sesbania punicea* (Cavanille) Bentham (Fabaceae) in South Africa (Hoffman 1990). A spectacular recent success was the control of the Australian acacia, *A. longifolia* (Andrews) Willdenow (Mimosaceae), in South Africa through damage from the gall wasp, *Trichilogaster acaciaelongifoliae* (Froggatt). Dennill (1988) and Dennill and Gordon (1991) have shown that the effects of the gall wasp on *A. longifolia* are particularly severe because gall production uses far more energy than normal growth and reproduction. There have been several less dramatic successes including the recent control of giant sensitive plant, *Mimosa invisa* Martius (Mimosaceae), with the sap-sucking bug *Heteropsylla spinulosa* Muddiman, Hodkinson and Hollis in coastal Queensland (White and Donnelly 1993).

History of exploration effort on prickly acacia

Prickly acacia has a broad native geographic range including much of Africa and central Asia (Figure 1). There are nine recognized subspecies with more or less distinct geographic ranges (Brenan 1983). The weed in Queensland is thought to be *A. nilotica indica* (Bentham) Brenan which is considered native to India and Pakistan. However, variation in pod form within Queensland, hearsay reports of introductions from Africa and at least one reported case of possible hybrid sterility suggest introductions may have been made from other regions. According to Brenan (1983), subspecies *indica* may also be native to north eastern Africa, further confusing the situation.

A search for biological control agents for prickly acacia commenced in 1980 when the Queensland Department of Lands subcontracted the International Institute of Biological Control's Pakistan Station. This five year project resulted in the field release of two insects, a seed-feeding bruchid, *Bruchidius sahlbergi* Schilsky, and a shoot-boring moth, *Cuphodes profluens* Meyrick (Julien 1992). Only the bruchid has become established. It is now widespread and destroying up to 80% of mature seeds, however, it appears to be having minimal impact on the spread of prickly acacia (M. Ablin personal communication). In 1989, a three year project began in Kenya. The first insect from this work, a leaf-feeding beetle *Weiseana barkeri* Jacoby, has been approved for release (Marohasy in press)

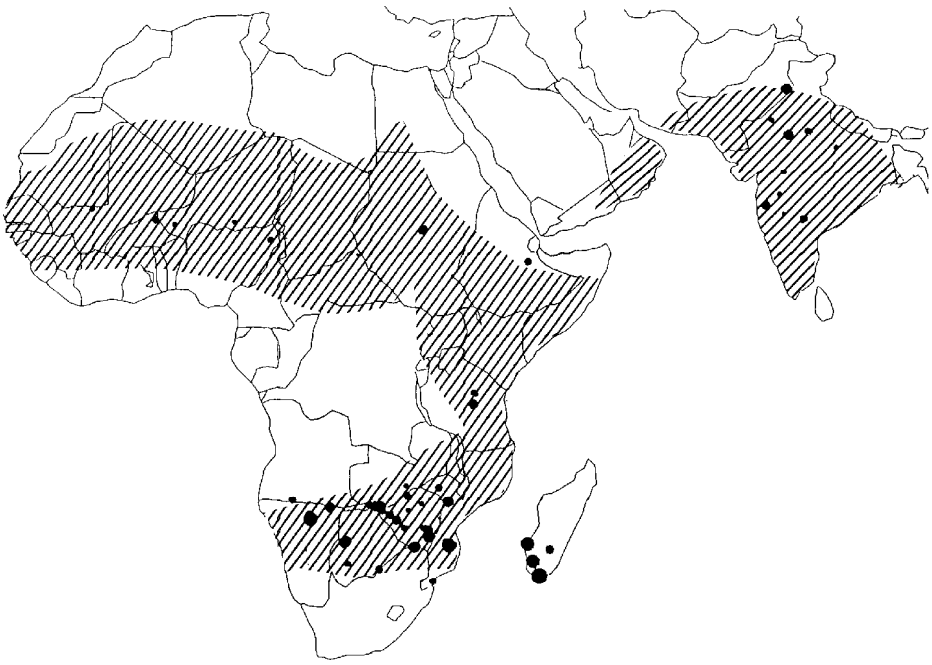

Figure 1. The native distribution of prickly acacia showing regions climatically similar to north west Queensland using the computer program *Climex*, Version 4.2, and target location Hughenden, Queensland. The larger the dot the better the climate match.

and field releases will begin in 1995 subject to supply of beetles from Kenya.

The projects in Pakistan (Mohyuddin 1980) and in Kenya (Marohasy 1993) and work in other regions, in particular by British colonial entomologists (Bhasin and Roonwall 1954, Peake 1954, Beeson 1961), indicates that there exists a large and diverse complex of insects attacking prickly acacia in its native range and that some species are very damaging. This paper lists all the insects recorded attacking prickly acacia and discusses the potential of some species for the control of prickly acacia in Queensland.

Insects known to attack prickly acacia in Africa and Asia

Insects known to feed on prickly acacia in its native range are listed in Table 1 according to their mode of feeding and country in which they were found. The list includes over 260 species but is incomplete since many areas of the extensive native range have not yet been explored.

Most species listed in Table 1 are either from Kenya, Pakistan or India. There was a very limited amount of information on insect species from Kenya and Pakistan before the respective biocontrol projects. The large number of insects recorded in India (Table 1) probably reflects the zeal of the British colonial entomologists and the importance of prickly acacia as a timber tree in that country.

With the exception of Kenya, relatively little is known about the insect fauna of prickly acacia in Africa. It is a dominant tree species through much of the Nile Valley in Egypt (Bytinski-Salz 1954, Halperin and Sauter 1991). It is an important timber tree further upstream with plantations being actively managed on the flood plains of the Blue Nile in the Sudan (Peake 1954, El Atta 1988) and is also common on the flood plains of the Senegel River in West Africa (Aubreville 1941). It is likely that surveys in these regions and also in southern Africa would result in the finding of many additional potential biological control agents. It is noteworthy that only three of the 72 insect species found attacking prickly acacia in Pakistan were also found in Kenya.

Potential biological control agents

Biological control agents for prickly acacia in Australia must be species-specific because the weed is closely related to the many native Australian acacias. Three Australian species of acacia are considered most at risk by the introduction of biological control agents into Australia because they are in the same subgenus as prickly acacia and also occur on the Mitchell grasslands. *A. bidwillii* Benth. and *A. sutherlandii* (F. Muell.) F. Muell. (both known as corkwood wattle) and *A. farnesiana* (L.) Willd. (mimosa bush).

Table 1. Insects recorded feeding on prickly acacia in its native range.

LEAF-FEEDING INSECTS

India

Achaea janata (Lep.: Noctuidae), (Bhasin and Roonwall 1954)
Archips micaceanus (Lep.: Tonricidae), (Browne 1968)
Archips pomivoros (Lep.: Tortricidae), (Browne 1968)
Ascotis infixaria (Lep.: Geometridae), (Bhasin and Roonwall 1954)
Cacoecia pomivora (Lep.: Geometridae), (Bhasin and Roonwall 1954)
Cacoecia isocyrta (Lep.: Tortricidae), (Bhasin and Roonwall 1954)
Cacoecia micacaeana (Lep.: Geometridae), (Bhasin and Roonwall 1954)
Capua detractana (Lep.: Tortricidae), (Browne 1968)
Chilena similis (Lep.: Lasiocampidae), (Bhasin and Roonwall 1954)
Clania crameri (Lep.: Psychidae), (Bhasin and Roonwall 1954)
Cryptothelea crameri (Lep.: Psychidae), (Browne 1968)
Cusiab raptaria (Lep.: Geometridae), (Bhasin and Roonwall 1954, Browne 1968)
Dasychira grotei (Lep.: Lymantriidae), (Bhasin and Roonwall 1954, Browne 1968)
Dereodus mastos (Col.: Curculionidae), (Bhasin and Roonwall 1954)
Diapromorpha balteata (Col.: Chrysomelidae), (Browne 1968)
Epagoge retractana (Lep.: Geometridae), (Bhasin and Roonwall 1954)
Euproctis lunata (Lep.: Lymantriidae), (Bhasin and Roonwall 1954, Browne 1968)
Euproctis scintillans (Lep.: Lymantriidae), (Bhasin and Roonwall 1954, Browne 1968)
Hyposidra successaria (Lep.: Geometridae), (Beeson 1961, Browne 1968)
Lymantria incerta (Lep.: Lymantriidae), (Bhasin and Roonwall 1954, Browne 1968)
Metanastria hyrtaca (Lep.: Lasiocampidae), (Bhasin and Roonwall 1954)
Ophiusa janata (Lep.: Noctuidae), (Browne 1968)
Schistocerca gregaria (Lep.: Orthoptera), (Browne 1968)
Semiothisa streniataria (Lep.: Geometridae), (Beeson 1961, Browne 1968)
Spatularia mimosae (Lep.: Lyonetiidae), (Browne 1968)
Stemocera diardi (Col.: Buprestidae), (Bhasin and Roonwall 1954, Browne 1968)
Stemocera laevigata (Col.: Buprestidae), (Bhasin and Roonwall 1954)
Stemocera orientalis (Col.: Buprestidae), (Bhasin and Roonwall 1954)
Sternocera chrysis (Col.: Buprestidae), (Browne 1963)
Streblote siva (Lep.: Lasiocampidae), (Browne 1968)
Taragama siva (Lep.: Lasiocampidae), (Bhasin and Roonwall 1954)
Tephrina disputaria (Lep.: Geometridae), (Bhasin and Roonwall 1954, Browne 1968)
Thiacidas postica (Lep.: Noctuidae), (Bhasin and Roonwall 1954, Browne 1968)
Traminda mundissima (Lep.: Geomet.), (Bhasin and Roonwall 1954, Browne 1968)

Kenya (from Marohasy unpublished data)
Acaciothrips ebneri (Thy.: Phaleothripidae)
Heliothrips haemorrhoidalis (Thy.: Thripidae) polyphagous
Leipoxais sp. (Lep.: Lasiocampidae)
Lophotheridae sp. (Orth.: Thericleidae), polyphagous
Myllocerus sp. (Col.: Curculionidae)
Myllocerus bayeri (Col.: Curculionidae)
Odontocheilopteryx ?*ungemachi* (Lep.: Lasiocampidae)
Orygia mixta (Lep.: Lymantridae), polyphagous
Prasinocyma nereis (Lep.: Geometridae), specific to *Acacia*
Prasinocyma sp. (Lep.: Geometridae)
Semiothisa ?*assimilis* (Lep.: Geometridae)
Semiothisa inconspicua (Lep.: Geometridae)[A]
Sesquialtera ridicula (Lep.: Geometridae)
Tephrina ?presbitaria (Lep.: Geometridae)
Tephrina sp. (Lep.: Geometridae), specific to subgenus *Acacia*
Weiseana barkeri (Col.: Chrysomelidae)[A]

Pakistan (from Mohyuddin unpublished data)
Amblyrhinus poricollis (Col.: Curculionidae)
Ascotis imparata (Lep.: Geometridae)
Chlorissa punctifimbria (Lep.: Geometrldae)[A]
Comibaena cassidera (Lep.: Geometrldae)[A]
Cortyta vetusta (Lep.: Noctuidae)
Euproctis lunata (Lep.: Lymantriidae)
Euproctis objecta (Lep.: Lymantriidae)
Euproctis subnotata (Lep.: Lymantriidae)
Euproctis scintillans (Lep.: Lymantriidae)

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The host plant range of most of the insects listed in Table 1 is not known. Host specificity testing has only been undertaken for some of the insects from Kenya (Marohasy 1993, Marohasy in press) and Pakistan (Mohyuddin unpublished data). These tests or extensive field observations indicate that seventeen species are specific or are likely to be specific to prickly acacia and would thus be suitable for introduction into Australia. These species are marked [A] in Table 1.

There are few reliable criteria for determining the likely effectiveness of these species as control agents (van Lentern 1980, Cullen 1992). There are two factors that will determine their potential effectiveness:

i. the type of damage they inflict and
ii. whether or not populations can build up to large enough numbers to affect the weed's population dynamics.

Obviously the more damaging the individual insect the lower the critical population number. Many factors affect the potential of an insect species to become abundant, including how well adapted it is to the new environment and levels of parasitism and predation. It is difficult to predict levels of parasitism and predation prior to the release and establishment of a control agent. Insects from similar climates (McFadyen 1991) and the same subspecies of prickly acacia would be expected to be better adapted. Figure 1 shows the regions in Asia and Africa climatically most similar to the Mitchell grasslands (Climex Version 4.2). The best matches within the native distribution of prickly acacia are in southern Africa. Mabote, Mozambique, and Tsumeb, Namibia, give the best match, both with a match index of 0.71. However, *A. nilotica kraussiana* (Bentham) Brenan which occurs here is morphologically least like the prickly acacia in Queensland. Lahore, Pakistan, gives the best match index for the Indian subcontinent with a match index of 0.65.

The mode of feeding of an insect species is a useful indication of the damage it may cause the host plant, and with an understanding of the biology of the weed can also give some indication of its potential to affect weed population dynamics (Briese 1993) . Potential control agents, their level of specificity and likelihood of becoming sufficiently abundant, are discussed under the following headings which relate to modes of feeding.

Leaf-feeding insects

Many different lepidopteran species are known to attack the foliage of prickly acacia in India, Pakistan and Kenya (Table 1). Preliminary host specificity tests indicate a Kenyan species of lepidoptera, *Semiothisa inconspicua* Warren (unpublished data) and a chrysomelid beetle

Table 1. continued from previous page

Gymnoscelis sp. (Lep.: Geometridae)
Hypolixus truncatulus (Col.: Curculionidae)
Imma sp. (Lep.: Glyphipterygidae)
Julodis whithilli (Col.: Buprestidae)
Myllocerus undecimpustulatus (Col.: Curculionidae)
Myllocerus transmarinus (Col.: Curculionidae)
Myllocerus laetivirens (Col.: Curculionidae)
Myllocerus spp. (Col.: Curculionidae)
Myllocerus tabricii (Col.: Curculionidae)
Nola analis (Lep.: Nolidae)
?*Nephopteryx* sp. (Lep.: Pyralidae)
Pachytychius viciae (Col.: Curculionidae)
Peltotorachelus juvencus (Col.: Curculionidae)
Phycita sp. (Lep.: Pyralidae)
Scythris sp. (Lep.: Scythridae)
Scythris camelella (Lep.: Scythridae)
Selepa celtis (Lep.: Noctuidae)
Streblota siva (Lep.: Lasiocampidae)
Tanymecus sp. (Col.: Curculionidae)
Tephrina disputaria (Lep.: Geometrldae)[A]

Nigeria (from Roberts 1969)
Amblyrhinus brunneus (Col.: Curculionidae)
Amblyrhinus instabalis (Col.: Curculionidae)
Clypsotidia conitera (Lep.: Noctuidae)
Cryptothelea junodi (Lep.: Psychidae)

Sudan (from Thornton 1957)
Auchmophila kordotensis (Lep.: Psychidae), specific to *Acacia*

SAP-SUCKING INSECTS

Egypt (from Girling unpublished)
Ceronema acaciae (Hem.: Coccidae) specific to *Acacia*

India
Anomalococcus indicus (Hem.: Coccidae), (Bhasin and Roonwall 1954)
Aspichproctus cinerea (Hem.: Coccidae), (Bhasin and Roonwall 1954)
Drosicha stebbingi (Hem.: Margarodidae), (Browne 1968)
Halys dentatus (Hem.: Pentatomidae), (Browne 1968)
Hemaspidoproctus cineres (Hem.: Margarodidae), (Browne 1968)
Laccifer lacca (Hem.: Coccidae), (Beeson 1961, Browne 1968)
Oxyrhachis tarandus (Hem.: Membracidae), (Browne 1968, Thakur 1973)

Kenya (from Marohasy unpublished)
Acaudaleyrodes sp. (Hem.: Aleyrodidae)
Accacidia sp. 1 (Hem.: Cicadellidae)
Accacidia sp. 2 (Hem.: Cicadellidae), specific to *Acacia*
Acizzia sp. (Hem.: Psylildae)[A]
Aphis craccivora (Hem.: Aphididae), polyphagous
Aspidoproctus sp. (Hem.: Margarodidae), specific to subgenus *Acacia*
Atelocera stictica (Hem.: Pentatomidae), polyphagous
Coccus longulus (Hem.: Coccidae)
Genus and species indeterminate (Hem.: Psyllidae), specitic to *Acacia*
Helionidia sp. (Hem.: Cicadellidae)
Icerya purchasi (Hem.: Margarodidae), polyphagous
Ledaspis reticulata (Hem.: Diaspididae)
Macropsis sp. (Hem.: Cicadellidae)
Myzus persicae (Hem.: Aphididae), polyphagous
Oxyrachis sp. (Hem.: Membracidae), specific to *Acacia*
Parasaissetia nigra (Hem.: Coccidae), polyphagous
Platacantha lutea (Hem.: Pentatomidae), specific to *Acacia*
Pseudoccocus sp. (Hem.: Pseudococcidae), specific to *Acacia*
Tachardina ?*brachystegiae* (Hem.: Kerridae)
Tetraleurodes sp. (Hem.: Aleyrodidae)
Waxiella mimosae (Hem.: Coccidae), specific to *Acacia*

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Pakistan
Aleurobbus niloticae (Hem.: Aleyrodidae), (Mohyuddin unpublished)
Anomalococcus indicus (Hem.: Coccidae), (Beeson 1964), specific to *Acacia* (Girling unpublished)
Coccus sp. (Hem.: Coccidae), (Mohyuddin unpublished)
Drosicha stebbingi (Hem.: Margarodidae), (Mohyuddin unpublished)
Erythroneura garhiensis (Hem.: Cicadellidae), (Ahmed 1970), specific to *Acacia* (Girling unpublished)
Flata sp. (Hem.: Flatidae), (Mohyuddin unpublished)
Homoeocerus prominulus (Hem.: Coreidae), (Mohyuddin unpublished)
Kerria ebrachiata (Hem.: Kerriidae), (Mohyuddin unpublished)
Ledropsis sp. (Hem.: Cicadellidae), (Mohyuddin unpublished)
Moonia sp. (Hem.: Cicadellidae), (Mohyuddin unpublished)
Nipaecoccus viridis (Hem.: Pseudococcidae), (Mohyuddin unpublished)
Oxyrhachis tarandus (Hem.: Membracidae), (Mohyuddin unpublished)

Sudan (from Girling unpublished)
Macropukinaria acaciae (Hem: Coccidae), specific to *Acacia*

GALLING INSECTS

Egypt (from Houard 1923)
Collula acaciae (Dip.: Cecidomyiidae)
Collula kiefferi (Dip.: Cecidomyiidae)

Kenya (from Gagné and Marohasy 1993)
Acacidiplosis imbricata (Dip.: Cecidomylidae)[A]
Acacidiplosis spinosa (Dip.: Cecidomyiidae)[A]
Aposchizomyia acuta (Dip.: Cecidomylidae)[A]
Lopesia niloticae (Dip.: Cecldomylidae)[A]
Asphondylia sp. (Dip.: Cecidomyiidae)

Pakistan (from Mohyuddin unpublished)
Cydia sp. (Lep.: Tortricidae)

GREEN SHOOT-BORING INSECTS

India
Sinoxylon anale (Col.: Bostrychidae), (Basin and Roonwall 1954, Browne 1968)
Sinoxylon sudanicum (Col.: Bostrychidae),(BasinandRoonwall 1954, Browne 1968)

Pakistan (from Mohyuddin unpublished)
Anarsia trlaonota (Lep.: Gelechildae)[A]
Ascalenia callynella (Lep.: Momphidae)[A]
Cuphodes profluens (Lep.: Gracillarildae)[A]
Gisilia stereodoxa (Lep.: Momphidae)

WOOD-BORING INSECTS

India
Aeolesthes holosericea (Col.: Cerambycidae), (Stebbing 1914)
Coelosterna scabrator (Col.: Cerambycidae), (Bhasin and Roonwall 1954, Beeson 1961) also attacks *Eucalyptus* (Sivaramakrishnan 1986)
Psiloptera coerulea (Col.: Buprestidae), (Stebbing 1914)
Psiloptera fastuosa (Col.: Buprestidae), (Stebbing 1914)
Bifiditermes beesoni (Isop.: Kalotermitidae), (Browne 1968)
Coptotermes heimi (Isop.: Kalotermitidae), (Kayani and Sheikh 1981)
Microtermes umicolor (Isop.: Kalotermitidae), (Kayani and Sheikh 1981)
Microcerotermes heimi (Isop.: Kalotermitidae), (Kayani and Sheikh 1981)
Microcerotermes championi (Isop.: Kaolotermitidae), (Kayani and Sheikh 1981)

Kenya (from Marohasy unpublished)
Sinoxylon cafrum (Col.: Bostrichidae)
Derolus sp. (Col.: Cerambycidae)

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W. barkeri Jacoby (Marohasy in press) and several Pakistani species of lepidoptera are specific to prickly acacia (Mohyuddin unpublished). However, precedence suggests leaf-feeding lepidoptera are unlikely to be successful control agents in Australia because they tend to be heavily parasitized (R.E. McFadyen personal communication). The chrysomelid *W. barkeri* has been approved for field release (Marohasy in press) and will be released in north west Queensland in 1995 subject to supply from Kenya.

Sap-sucking insects

Two species of psyllid attack prickly acacia in Kenya (Table 1). An extensive field survey in Kenya indicated one species, *Acizzia* (new species), is specific to prickly acacia, however, attempts to establish a colony in quarantine in Brisbane were unsuccessful (B. Willson personal communication). Preliminary cage tests in Kenya resulted in the abandonment of the scale insects *Aspidoproctus* sp. and *Waxiella mimosae* because these tests indicated the species had broader host ranges than a field survey suggested (unpublished data). Mohyuddin (unpublished) made only brief reference to sap-sucking insects in his report and listed no species of psyllid.

Galling insects

Gagné and Marohasy (1993) describe 28 species of gall midge from five species of *Acacia* in Kenya. Most midge species are specific to a single species of *Acacia* with four species being specific to prickly acacia. *Acacidiplosis spinosa* Gagné is the most common and appears the most damaging species attacking prickly acacia in Kenya (Marohasy 1993). Prickly acacia, like many leguminous species, produces many more flowers than it has the resources to mature and most of these are shed (Stephenson 1981, Tybirk 1988). Interestingly flowers galled by *A. spinosa* are not shed but develop into galls which act as energy sinks, consuming resources which would otherwise be available for growth and pod maturation. Successful biocontrol of *A. longifolia* (Andrews) Willdenow has been achieved in South Africa using a wasp which galled flowers (Dennill 1988). Dennill (1988) reported that the wasp sometimes committed *A. longifolia* to the production of 200% more galls per branch than the normal quota of pods and dubbed this phenomena "forced commitment". However, testing of *A. spinosa* has not been possible to date because potted specimens of prickly acacia do not flower (Marohasy 1993) and it therefore can not be cage tested in quarantine.

Acacidoplosis imbricata Gagné, which also galls developing flowers, is closely related to *A. spinosa* but rarer in Kenya.

However, it has a broader distribution, being also present in South Africa and Zimbabwe on *A. nilotica kraussiana* (Bentham) Brenan (personal observations). Another species of midge, *Aposchizomyia acuta*, forms a large lumpy gall, typically at the stem apex and inhibits stem elongation. It is known that stem elongation in prickly acacia occurs immediately before the development of buds and flowers and that buds and flowers are only produced on green extending shoots (Milton 1987). Through the inhibition of stem elongation this midge effectively stops the production of flowers on affected stems.

Green shoot-boring insects

No green shoot-boring species were found in Kenya (Marohasy unpublished), although four species of lepidoptera were recorded by Mohyuddin (unpublished) in Pakistan (Table 1). Two of the four species, *Cuphodes profluens* Meyrick and *Ascalenia callynella* Kasy, were shown to be host specific (Mohyuddin unpublished). A third species, *Anarsia triaenota* Meyrick, could complete development on the Australian native *A. victoria*e Bentham in a cage starvation situation (Mohyuddin unpublished). Only *C. profluens* was field released in Queensland. It has not established (B. Willson personal communication). *A. callynella* could be considered for introduction in the future.

Wood and stem-boring insects

One hundred and twenty trees were felled and cut into metre long portions in Kenya in search of wood boring insects but only two species were found, both beetles (Table 1), and these only in small numbers (Marohasy unpublished data). Mohyuddin (1986) reported no species from Pakistan while nine species have been recorded from India by earlier workers. Given the potential of this groups of insects to inflict structural damage to trees, more information should be sought on the nine species recorded from India (Table 1).

Root-boring insects

Root-boring insects can be damaging but are difficult to rear and test for host specificity. The roots of prickly acacia in Kenya and Pakistan were not searched for insects. *Coelosterna scabrator* is apparently very damaging to prickly acacia plantations in India but is unsuitable because it also attacks *Eucalyptus* plantations (Ralph 1985).

Ring-barking insects

No ring-barking species were found in Kenya. Mohyuddin (unpublished) lists four species from Pakistan but gives no indication of their host plant ranges. Peake (1954) and El Atta (1988) attributed

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ROOT-BORING INSECTS

India
Coelostema scabrator (Col.: Cerambycidae), (Browne 1968) also attacks *Eucalyptus* (Ralph 1985)
Chrysobothris gardneri (Col.: Buprestidae), (Browne 1968)
X*ylocopa fagani* (Col.: Melolonthidae), (Clifford 1884)

RING-BARKING INSECTS

India
Acmaeodera aurifera (Col.: Buprestidae), also attacks Acacia catechu (Browne 1968)
Psiloptera cupreosplendens (Col.: Buprestidae), (Beeson 1961, Browne 1968)
Psiloptera fastuosa (Col.: Buprestidae), (Beeson 1961, Browne 1968)
Cyrtozemia cognata (Col: Curculionidae) (Browne 1968)

Pakistan (from Mohyuddin unpublished)
Niphona fuscatrix (Col.: Cerambycidae)
Arthrolips sp. (Col.: Corylophidae)
Genus and species unknown (Lep.: Gelechidae)
Acrocercops ?diatomiea (Lep.: Gracillariidae)

Sudan (from Peake 1954)
Sphenoptera fulgens (syn. *Sphenoptora chalolchrw arenosa*) (Col.: Buprestidae)[A]
Agrilus discolorigormis (Col.: Buprestidae)

FLOWER-FEEDING INSECTS

India (from Bhasin and Roonwall 1954)
Azanus ubaldus (Lep.: Lycaenidae)
Azanus uranus (Lep.: Lycaenidae)

Kenya (from Marohasy unpublished)
Anarsia spp. 1, 2, 3, 4, 5 and 6 (Lep.: Gelechidae)
Anthene definita (Lep.: Lywaenidae), polyphagous
Ascalenia spp. 1, 2, 3, 4 and 5 (Lep.: Cosmopterygidae)
Azanus ubaldus (Lep.: Lycaenidae), also feeds lucerne
Azanus mirza (Lep.: Lycaenidae), also feeds *Dichrostachys* sp. and *Allophylus* sp. (Sapindaceae)
Chbroclystis nanula (Lep.: Geometridae)
Chloroclystis consocer (Lep.: Geometridae)
Chloroclystis sp. (Lep.: Geometridae)
Cryptoblabes gnidiella (Lep.: Pyralidae), also feeds on *Ceratonia* sp.
Eublemma ecthaemata (Lep.: Noctuidae)
Eucosma sp.?*calculosa* (Lep.: Tortricidae)
Genus and species indeterminate (Dip.: Cecidomyiidae)
Gisilia stereodoxa (Lep.: Momphidae)
Homodaula calamitosa (Lep.: Yponomeutidae)
Hypatima sp. (Lep.: Yponomoutidae)
Nanophytes sp. nr. *conradsi* (Col.: Apionidae)
Nola sp.?*imitata* (Lep.: Noctuidae)
Nola melalopha (Lep.: Noctuidae)
Oncocera sp. (Lep.: Pyralidae)
Pardasena virgulana (Lep.: Noctuidae), polyphagous
Prasinocyma sp. 1 and 2 (Lep. : Geometridae)

Pakistan (from Mohyuddin unpublished)
Anarsia reciproca (Lep.: Gelechiidae), polyphagous
Anarsia sp. (Lep.: Gelechiidae), also feeds *A. famesiana*
Autoba silicula (Lep.: Noctuidae)
Azanus ubaldus (Lep.: Lywaenidae)
Azanus uranus (Lep.: Lycaenidae)
Ceutholopha isidis (Lep.: Pyralidae), polyphagous
Comibaena cassidara (Lep.: Geometridae)
Cryptophilus integer (Col.: Languriidae)
Heterographis sp. (Lep.: Pyralidae)

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Table 1. continued from previous page

Metisa sp. (Lep.: Psychidae)
Pseudosterrha paulula (Lep.: Geometridae)
Rapala iarbus (Lep.: Lycaenidae)
Scythris glyphidota (Lep.: Scythrididae)

GREEN SEED-FEEDING INSECTS

India
Cryptophlebia illepida (Lep.: Tortricidae), (Browne 1968)

Kenya (from Marohasy unpublished)
Anarsia spp. (Lep.: Gelechiidae)
Atelocera stictica (Hem.: Pentatomidae), polyphagous
Calidea bohemanni (Hem.: Pentatomidae), polypagous
Cryptophlebia ombrodelta (Lep.: Tortricidae), polyphagous
Cryptophlebia peltastica (Lep.: Tortricidae)
Cryptophlebia leucotreta (Lep.: Tortricidae), polyphagous
Homoeocerus trimaculatus (Hem.: Coreidae)
Naricus cinctiventris (Hem.: Alydidae)
Risbecoma capensis (Lep.: Eurytomidae), specific to subgenus *Acacia*

Nigeria (from Roberts 1969)
Characoma nilotica (Lep.: Noctuidae)

Sudan (from Peake 1952)
Bruchidius uberatus (syn. *Bruchidius baudoni*) (Col.: Bruchidae), also feeds on *Abutilon* sp. and *Dolichos lablab*

MATURE SEED-FEEDING INSECTS

India (from Browne 1968)
Araecerus suturalis (Col.: Anthribidae)
Caryedon gonagra (Col.: Bruchidae)

Kenya (from Marohasy unpublished)
Bruchidius grandemaculatus (Col.: Bruchidae), specific to subgenus *Acacia*
Bruchidius sp. 1 and 2 (Col.: Bruchidae)
Bruchidius latevalvus (Col.: Bruchidae)
Bruchidius uberatus (Col.: Bruchidae)
Caryedon serratus (Col.: Bruchidae), polyphagous
Tuberculobruchus sp. (Col.: Bruchidae)
Enaretta castelnaudi (Col.: Cerambycidae), polyphagous
Sibina sp. (Col.: Curcuiionidae)
Virachola livia (Lep.: Lywaenidae), polypagous
Characoma ?ferrigrisea (Lep.: Noctuidae)
Cryptoblales gnidiella (Lep.: Pyralidae), polyphagous
Phthoropoea pycnosaris (Lep.: Tineidae), polyphagous
Phthoropoea oenochares (Lep.: Tineidae)

Pakistan (from Mohyuddin unpublished)
Bruchidius sp. 1, 2 (Col.: Bruchidae)[A]
Bruchidius sp. 3 (Col.: Bruchidae)
Bruchidius sahlbergi (Col.: Bruchidae)[A]
Bruchidius andrewesi (Col.: Bruchidae), also feed *A. farnesiana*
Caryedon serratus (Col.: Bruchidae), polyphagous
Lasioderma serricome (Col.: Anobiidae), polyphagous
Migneauxia orientalis (Col.: Lathridiidae), polyphagous
Stathmopoda auriferella (Lep.: Stathmopodiidae)
Sulcobruchus sp. (Col.: Bruchidae), also feeds A. *farnesiana*

Sudan (from Peake 1952)
Bruchidius baudoni (Col.: Bruchidae), polyphagous
Bruchus centromaculatus (Col. Bruchidae), also attacks *Dichrostachys nutans*
Bruchus quadrimaculatus (Col.: Bruchidae), specific to Mimosoideae
Bruchus submaculatus (Col.: Bruchidae), also attacks *Albizia* sp. and *Combretum* sp.
Bruchus theobromae (Col.: Bruchidae)

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die-back in prickly acacia plantations in the Sudan to damage from the buprestid beetle *Sphenoptera fulgens* Gory. However, other Sudanese foresters consider the beetle to be secondary and not the cause of the die back (M. Gasim Musa, M. Elfadul and A. El Salam Kahid Abdul El Salam personal communication). Permission was received from the Australian Quarantine and Inspection Service (AQIS) to import the beetle into quarantine in Brisbane directly from the Sudan without preliminary host testing, however, insufficient numbers were received to start a colony (B. Willson personal communication).

Flower-feeding insects

The flowers of prickly acacia in Kenya and Pakistan are almost exclusively utilized by species of lepidoptera (Table 1) with no species specific to pricky acacia (Mohyuddin unpublished, Marohasy and Hongo unpublished). Given that over 99% of the flowers produced by prickly acacia are normally shed (Tybirk 1988), it is likely an unrealistically large percentage of flowers would need to be destroyed for these insects to have any impact on seed production (Marohasy 1993).

Seed-feeding insects

Bruchidius sahlbergi Schilsky, together with the Australian native weevil *Carreydon serratus* (Oliv.), destroy a large percentage of prickly acacia seed in Queensland but appear to be having a limited effect on its spread. A large percentage of seed is eaten by stock and remains viable in cow dung where it is inaccessible to these insects as they will only search for seed in pods under or on trees.

In contrast, insects which attack unripe green seed may be effective control agents as they can access the seed before it falls to the ground and is fed on by stock. In this way they have access to the total resource and if insect numbers are high could destroy a very large percentage of seed (Marohasy 1993). The wasp, *Risbecoma capensis* (Walker) is the most promising insect in this category, however, it may also attack the three native Australian acacias *A. bidwilli*, *A. farnesiana* and *A. sutherlandii* (Marohasy unpublished data) and thus permission for its field release is unlikely.

Conclusion

Prickly acacia is known to be attacked by a great diversity of insect species in the few regions where its insect fauna has been studied. There are seventeen insect species which are likely to be host specific to prickly acacia in Pakistan and Kenya alone. However, of these species the potentially most damaging insects can not currently be reared because of technical problems associated with supplying

Table 1. continued from previous page

Bruchus albonotatus (Col.: Bruchidae)
Bruchus albosparsus (Col.: Bruchidae), also attacks cotton
Bruchus analis (Col.: Bruchidae)
Bruchus bedfordi (Col.: Bruchidae)
Pachymerus cassiae (Col.: Bruchidae), also attacks *Cassia*, *Prosopis* and *Eucalyptus*
Pachymerus longus (Col.: Bruchidae), also attack *A. albida*
Pachymerus pallidus (Col.: Bruchidae), pest of *Cassia*

South Africa
Bruchus baudoni (Col.: Bruchidae), (Anonymous 1970)
Bruchidius securiger (Col.: Bruchidae), (van Tonder 1981)
Bruchidius uberatus (Col.: Bruchidae), (van Tonder 1981)
Pygobruchidius latiorithorax (Col.: Bruchidae), (van Tonder 1981)

SEED-FEEDING INSECTS

India (from Bhasin and Roonwall 1954)
Araecerus suturalis (Col.: Anthribidae)
Argyroploce illepida (Lep.: Eucosmidae)
Pachymerus gonagra (Col.: Bruchidae)
Pyloetis mimosae (Lep.: Lyonetidae)

Nigeria (from Roberts 1969)
Bruchidius uberatus (Col.: Bruchidae)
Caryedon albonotatum (Col.: Bruchidae)

South Africa (from Anonymous 1970)
Enaretta intermedia (Col.: Cerambycidae)

[A] Species are specific, or likely to be specific, to prickly acacia.

plants of the correct phenological stage. More host specific insect species are likely to be found in other parts of prickly acacia's range, in particular in the semi-arid regions of Africa which have not yet been surveyed.

In conclusion, there is potential for successful biological control of prickly acacia. However, the program presents unique challenges which will only be overcome through a high level of commitment to research both in Australia and in some of the logistically most difficult parts of the world.

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