Gall thrips *Acaciothrips ebneri* (Thysanoptera: Phlaeothripidae) from Ethiopia, a promising biological control agent for prickly acacia in Australia

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Based on climatic and plant phenotype matching, native-range surveys were conducted in Ethiopia to identify prospective biological control agents for prickly acacia, a serious weed of grazing areas in northern Australia. Surveys identified a gall thrips, *Acaciothrips ebneri* (Karny) (Thysanoptera: Phlaeothripidae), as a prospective biological control agent for prickly acacia, based on damage potential, field host range and geographic range in Ethiopia. The gall thrips was imported into a high security quarantine facility at the Ecosciences Precinct, Brisbane, Australia in December 2015 and host-specificity tests are in progress. If approved, the gall thrips would be the first gall insect to be released against prickly acacia in Australia.

Prickly acacia, *Vachellia nilotica* subsp. *indica* (Benth.) Kyal. & Boatwr. (Syn: *Acacia nilotica* subsp. *indica*), is a serious weed of grazing areas in western Queensland and has the potential to spread throughout northern Australia (Dhileepan 2009). Prickly acacia infests over 6 million ha of natural grasslands and over 2000 km of bore drains (a free-flowing Great Artesian Basin bore) in Queensland, and has been estimated to cost primary producers AUD $9 million annually due to lost pasture production (Dhileepan 2009). Prickly acacia forms impenetrable thorny thickets, restricts stock access to watercourses, competes with native pasture species, and poses a threat to nearly 25 rare and threatened animal species and two endangered plant communities (Spies & March 2004). Biological control is the most economically viable management option for prickly acacia (Dhileepan 2009).

Biological control efforts commenced in the early 1980s, with native-range surveys conducted in Pakistan, Kenya, South Africa and India (Dhileepan 2009; Dhileepan *et al*. 2014). These surveys resulted in the introduction of five agents, but only two of them, a seed-feeding bruchid *Bruchidius sahlbergi* Schilsky (Coleoptera: Chrysomelidae) from Pakistan and a leaf-feeding looper *Chiasmia assimilis* (Warren) (Lepidoptera: Geometridae) from Kenya and South Africa have become established (Palmer *et al.* 2012). The impact of *B. sahlbergi* on prickly acacia has been insignificant (Radford *et al.* 2001), while *C. assimilis* has established only at coastal sites, and not in the inland regions, where major prickly acacia infestations occur (Palmer *et al.* 2007). The need for effective biological control for prickly acacia remains a high priority.

Historically, the establishment of biological control agents, introduced into Australia for the control of prickly acacia, has been poor (Senaratne *et al.* 2006). These agents, although shown to be specific to prickly acacia for release, may not have been adapted to survive the harsh climatic and environmental conditions of western Queensland. Hence, the climate modelling software CLIMEX was used to prioritise climatically suitable areas in the native-range for exploration and sourcing of biological control agents. However, instead of the widely used 'climate matching' approach, a climatic response model was developed based on an Ecoclimatic Index, for a hypothetical insect that would be naturally distributed in the Mitchell Grass Downs in the northwest Queensland (Senaratne *et al*. 2006). Prickly acacia is a serious problem in this region and only one of the six biological control agents released have become established there. This model was then used to identify climatically suitable areas for exploration and sourcing of agents in the native-range. Areas in eastern Africa were identified as most climatically similar to the hot and arid

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Received 11 August 2017. Accepted 12 December 2017

ISSN 1021-3589 [Print]; 2224-8854 [Online]
DOI: https://doi.org/10.4001/003.026.0237

regions of western Queensland and thus prioritised for sourcing new biological control agents (Senaratne *et al.* 2006). A literature search (Dwivedi 1993) and herbarium records (National Herbarium, Addis Ababa, Ethiopia) suggested that *V. nilotica* occurs in Ethiopia and hence, search efforts for new biological control agents were redirected to Ethiopia. In this study, based on field host range, damage potential and geographic range, we report a gall thrips *Acaciothrips ebneri* (Karny) (Thysanoptera: Phlaeothripidae) from Ethiopia as a prospective biological control agent for prickly acacia in Australia.

Potential survey sites in Ethiopia were identified based on herbarium records and the CLIMEX model. Surveys were conducted at 22 sites in July 2014, at 41 sites in December 2015, at 26 sites in November 2016, and at 14 sites in November 2017, in the Adama, Arba Minch, Awash, Dire Dawa, Harar, Melka Werer, Mille, Woldia, Mekele and Shewa Robit areas (Fig. 1). At each survey site, incidence of insects or insect damage were recorded, along with details on the *V. nilotica* subspecies status, plant stage (seedlings, juveniles or trees) and co-occurring vegetation (*e.g.* other *Vachellia* species). Field host range of various arthropods collected on prickly acacia was ascertained by investigating co-occurring *Vachellia* species (specifically looking for insects and mites found on *V. nilotica* trees; Dhileepan *et al*. 2013) at the survey sites. Priority was given to galling agents in view of their expected host-specificity (Raman 1984).

Surveys identified natural populations of three prickly acacia (*V. nilotica* (*L.)* P.J.H.Hurter & Mabb) subspecies (subsp. *tomentosa* (Benth.) Kyal. & Boatwr., subsp. *indica* (Benth.) Kyal. & Boatwr., and subsp. *leiocarpa* (Brenan) Kyal. & Boatwr.) in Ethiopia (Fig. 1). Though the possible existence of *V. nilotica* subsp. *indica* in Ethiopia has been suggested previously (Dwivedi 1993), for the first time, natural populations of *V. nilotica* subsp. *indica* have been identified in Ethiopia. The subspecies in the north (*i.e*. Amhara region) are predominantly *V. nilotica* subsp. *tomentosa*, the subspecies in the east (*i.e*. Afar region) are either *V. nilotica* subsp. *tomentosa* or *V. nilotica* subsp. *indica*; while subspecies in the south (*i.e.* Oromia) are predominantly *V. nilotica* subsp. *leiocarpa*. Additionally, the invasive prickly acacia in Australia, *V. nilotica* subsp. *indica,* is also very similar to *V. nilotica* subsp. *tomentosa* (the immature pods and young branchlet tips in subsp. *tomentosa* are tomentose, while in subsp. *indica* young branchlet tips are glabrous to sub-glabrous or thinly pubescent). The occurrence of *V. nilotica* subsp. *indica,* and other morphologically similar subspecies of *V. nilotica*, along with other closely related *Vachellia* species, make Ethiopia an ideal country to look for species and subspecies specific natural enemies as prospective biological control agents.

For the first time, the thrips *A. ebneri* which induces rosette galls, was recorded on prickly acacia in Ethiopia. Thrips galls were widespread in the northern and eastern regions of Ethiopia (Fig. 1), on both juvenile plants and mature trees. Thrips-induced galls were found on shoot tips and sprouting axillary buds, with the rudiments of leaves near the feeding sites converted into bunches of rosette-like structures (Fig. 2). In quarantine in Australia and under field conditions in Ethiopia, as a direct result of galling, the entire apical regions of the shoots were completely deformed, often causing shoot-tip dieback. Adult thrips fed on axillary and terminal buds and early signs of gall initiation became evident within a week under quarantine glasshouse conditions (27 °C, 60 % RH, and natural photoperiod). In the first week, shoot tips swelled and turned red in colour. The gall continued to grow in size and within three weeks new nymphs were observed in the gall. After four weeks, galls became inundated with new progeny adults, and when mature, turned black (due to necrosis) and began to die back. The gall thrips completed a generation in four to five weeks, as evident from progeny emergence from the gall.

Acaciothrips ebneri was seen on *V. nilotica* subsp. *tomentosa* at 79 % of sites at which the subspecies was present (n = 23) and *V. nilotica* subsp. *indica* at 96 % of sites at which the subspecies was present (n = 24), both subspecies of which have moniliform pods, but not on *V. nilotica* subsp. *leiocarpa* (n = 8) which has pod margins straight or crenate (Fig. 1). *Acaciothrips ebneri* was not observed on *Vachellia etbaica* (Schweinf.) Kayl. & Boatwr. (n = 9 sites), or *V. abyssinica* (Hochst. ex. Benth) Kyal. & Boatwr (n = 12 sites), or *Vachellia seyal* (Delile) P.J.H. Hurter (n = 4 sites), which co-occurred at some of the sampling sites. Based on the observed field host range, perceived damage potential and geographic range, *A. ebneri* was exported to a quarantine facility at the Agricultural Research Council-Plant Protection Research Institute

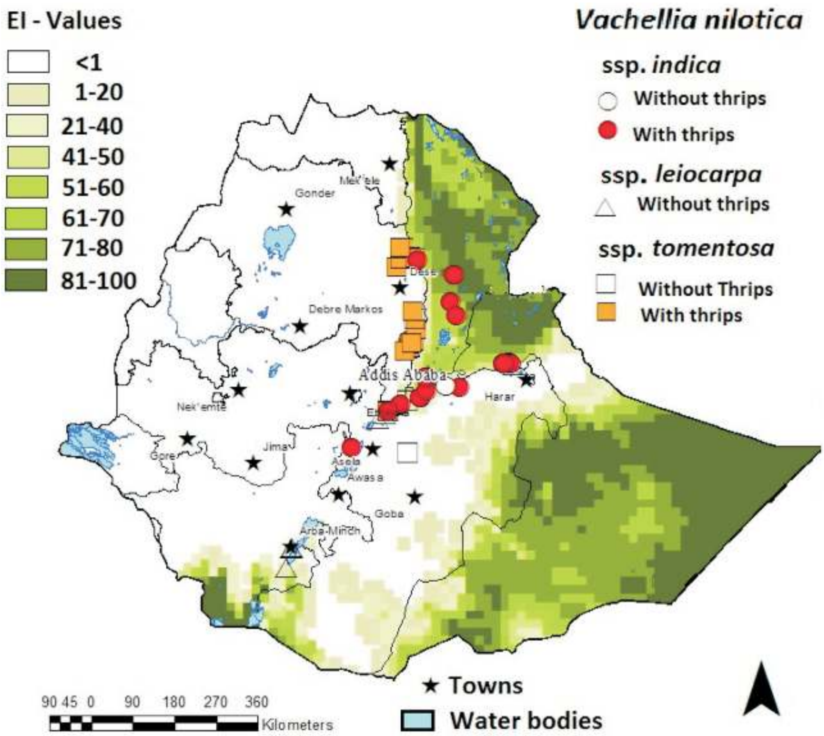

Fig. 1. Map of Ethiopia showing climatically suitable areas for native-range surveys, sampling sites, sampling sites with various *Vachellia nilotica* subspecies and sites with gall thrips. Higher EI (Ecoclimatic Index) values reflect greater climatic suitability. The climatic suitability estimated by interpolation of EI values from a CLIMEX model (Temperature Index: DV0 = 20, DV1 = 25, DV2 = 35, DV3 = 40; Moisture Index: SM0 = 0.001, SM1 = 0.003, SM2 = 0.2, SM3 = 0.3; Cold Stress: DTCS = 17, DHCS = –0.0005; Heat Stress: TTHS = 40, THHS = 0.001; Wet Stress: SMWS = 0.3, HWS = 0.04).

Fig. 2. Thrips-induced rosette galls in the terminal bud of a juvenile plant, resulting in shoot-tip deformation and dieback in *Vachellia nilotica* subsp. *tomentosa* in Ethiopia.

(ARC-PPRI), Pretoria, South Africa, for preliminary screening. The susceptibility of the Australian prickly acacia (*V. nilotica* subsp. *indica*) to *A. ebneri* was compared to that of the southern African endemic prickly acacia (*V. nilotica* subsp. *kraussiana*). In these preliminary studies (with a minimum of five replications for each subspecies), *A. ebneri* induced galls only on the Australian prickly acacia (*V. nilotica* subsp. *indica*), but not on southern African endemic *V. nilotica* subsp. *kraussiana* (with fruit pod margins straight or crenate). Though *V. nilotica* subsp. *indica* is considered to be a native of the Indian subcontinent, no specialist galling insects or mites have ever been reported on the subspecies from India or Pakistan. This is the first time that a specialist galling insect has been reported on the subsp. *indica* anywhere globally.

Acaciothrips ebneri has been previously reported from Nigeria, Sudan, Egypt and Senegal (ThripsWiki 2016), as part of taxonomic studies. Except for Senegal where it was reported from galls in *V. nilotica* (Bournier 1994), host records for the other countries are not known. It is likely that *A. ebneri* occurs on *V. nilotica* subspecies endemic to these countries – *V. nilotica* subsp. *indica* (Ethiopia), *V. nilotica* subsp. *tomentosa* (Nigeria, Sudan and Senegal), *V. nilotica* subsp. *nilotica* (L.) P.J.H. Hurter & Mabb (Egypt), and *V. nilotica* subsp. *adstringens* (Schumach. & Thonn.) Kyal. & Boatwr (Nigeria and Senegal). So far there are no other host records for *A. ebneri* other than *V. nilotica*. Field observations in Ethiopia and preliminary host-specificity tests involving two *V. nilotica* subspecies in South Africa suggest that *A. ebneri* is host specific, with host range restricted to *V. nilotica* subspecies with moniliform fruit pods (subsp. *tomentosa* and subsp. *indica*). Based on the field host range in Ethiopia and susceptibility of Australian prickly acacia in quarantine in South Africa, *A. ebneri* was imported into a high security quarantine facility at the Ecosciences Precinct, Brisbane, Australia, in December 2015 and a colony of *A. ebneri* has been established. To date over 55 test plant species have been screened and *A. ebneri* has induced galls and reproduced only on prickly acacia. Galling by *A. ebneri* on *V. nilotica* subsp. *indica* in quarantine resulted in shoot tip dieback. Host-specificity tests are still in progress. If approved, *A. ebneri* would be the first gall insect to be released against prickly acacia in Australia.

ACKNOWLEDGEMENTS

We thank L. Mound (CSIRO, Canberra, Australia) for identifying the gall thrips, R. Price (ARC-PPRI, Pretoria, South Africa) for the quarantine facilities in Pretoria, and the Ethiopian Biodiversity Institute for providing the permit to export the gall thrips. The study was carried out under the Queensland Government's 'War on Western Weeds' initiative. Funding support from the Meat & Livestock Australia, Rural Industries Research & Development Corporation and Rural Research & Development for Profit Programme of the Australian Government (Department of Agriculture and Water Resources) is gratefully acknowledged.

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REFERENCES

BOURNIER, A. 1994. Thysanoptera from Senegal: new species and genera. *Annales de la Société Entomologique de France* **30**: 419–429.

DHILEEPAN, K. 2009. *Acacia nilotica* ssp. *indica* (L.) Wild. Ex Del. (Mimosaceae). In: Muniappan, R., Reddy, G.V.P. & Raman, A. (Eds) *Biological Control of Tropical Weeds using Arthropods*. 17–37. Cambridge University Press, Cambridge, U.K.

DHILEEPAN, K., BALU, A., SENTHILKUMAR, P., MURUGESAN, M. & SHIVAS, R. 2013. Survey and prioritisation of potential biological control agents for prickly acacia (*Acacia nilotica* ssp. *indica*) from southern India. *Biocontrol Science and Technology* **23**: 646–664.

DHILEEPAN, K., TAYLOR, D.B.J., LOCKETT, C.J., BALU, A., SEIER, M., MURUGESAN, S., TANNER, R.A., POLLARD, K.M., KUMARAN, N. & NESER, S. 2014. Biological control of prickly acacia (*Vachellia nilotica* subsp. *indica*): current research and future prospects. In: Impson, F.A.C., Kleinjan, C.A. & Hoffmann, J.H. (Eds) *Proceedings of the XIV International Symposium on Biological Control of Weeds*. 21–30. 2–7 March 2014, University of Cape Town, Cape Town, South Africa.

DWIVEDI, A.P. 1993. *Babul* (Acacia nilotica): *A Multipurpose Tree of Dry Areas*. Arid Forest Research Institute, Indian Council of Forestry Research and Education, Jodhpur, India.

PALMER, W.A., LOCKET, C.J. & DHILEEPAN, K. 2012. *Acacia nilotica* ssp. *indica* – prickly acacia. In: Julien, M., McFadyen, R.E. & Cullen, J. (Eds) *Biological Con-*

trol of Weeds in Australia: 1960–2010. 18–28. CSIRO Publishing, Melbourne, Australia.

PALMER, W.A., LOCKETT, C.J., SENARATNE, K.A.D.W. & McLENNAN, A., 2007. The introduction and release of *Chiasmia inconspicua* and *C. assimilis* (Lepidoptera: Geometridae) for the biological control of *Acacia nilotica* in Australia. *Biological Control* **41**: 368–378.

RADFORD, I.J., NICHOLAS, D.M. & BROWN, J.R., 2001. Assessment of biological control impact of seed predators on the invasive shrub *Acacia nilotica* (prickly acacia) in Australia. *Biological Control* **20**: 261–268.

RAMAN, A. 1984. Gall insect–host plant relationships – an ecological perspective. *Proceedings: Animal Sciences* **93**: 293–300.

SENARATNE, K.A.D.W., PALMER, W.A. & SUTHERST, R.W. 2006. Use of CLIMEX modelling to identify prospective areas for exploration to find new biological control agents for prickly acacia. *Australian Journal of Entomology* **45**: 298–302.

SPIES, P. & MARCH, N. 2004. *Prickly acacia: National Case Studies Manual.* Natural Heritage Trust and Department of Natural Resources and Mines, Queensland, Australia. Online at: http://weeds.ala.org.au/WoNS/pricklyacacia/docs/Prickly_Acacia_Mgmnt-1.pdf (accessed 11 August 2017).

THRIPSWIKI. 2016. ThripsWiki – providing information on the world's thrips. Online at: http://thrips.info/wiki/Acaciothrips_ebneri (accessed 2 June 2016).