13. Grattapaglia, D. and Sederoff, R., *Genetics*, 1994, **137**, 1121–1137.
14. Sobral, B. W. and Honeycutt, R. J., *Theor. Appl. Genet.*, 1993, **86**, 105–112.
15. Postlethwait, J. H. *et al.*, *Science*, 1994, **264**, 699–703.
16. Reiter, R. S., Williums, J. G. K., Feldmann, K. A., Rafalski, J. A., Tingey, S. V. and Scolnik, P. A., *Proc. Natl. Acad. Sci. USA*, 1992, **89**, 1477–1481.
17. Huff, D. R., Peakall, R. and Smouse, P. E., *Theor. Appl. Genet.*, 1993, **86**, 927–934.
18. Dawson, I. K., Chalmers, K. J., Waugh, R. and Powell, W., *Mol. Ecol.*, 1993, **2**, 151–159.
19. Fegan, M., Manners, J. M., Maclean, D. J., Irwin, J. A., Samuels, K. D., Holdom, D. G. and Li, D. P., *J. Gen. Microbiol.*, 1993, **139**, 2075–2081.
20. Yu, K. and Pauls, K. P., *Theor. Appl. Genet.*, 1993, **86**, 788–794.
21. Black, W. C., Duteau, N. M., Puterka, G. J., Nechols, J. R. and Pettorini, J. N., *Bull. Entomol. Res.*, 1992, **82**, 151–159.
22. Baird, E., Cooper-Bland, S., Waugh. R., Demaine, M. and Powell, W., *Mol. Gen. Genet.*, 1992, **233**, 469–475.
23. McGowan, A. P., O Donaghue, K., Nicholls, S., McLauchlin, J., Bennett, P. M. and Reeves, D. S., *J. Med. Microbiol.*, 1993, **38**, 322–327.
24. Yu, L. X. and Nguyen, H. T., *Theor. Appl. Genet.*, 1994, **87**, 668–672.
25. Tibayrene, M., Neubauer, K., Barnabe, C., Guerrini, F., Skarecky, D. and Ayala, F. J., *Proc. Natl. Acad. Sci. USA*, 1993, **90**, 1335–1339.
26. Stiles, J. I., Lemme, C., Sondur, S., Morshidi, M. B. and Manshardt, R., *Theor. Appl. Genet.*, 1993, **85**, 697–701.
27. Levi, A., Rowland, L. J. and Hartung, J. S., *Hortic. Sci.*, 1993, **28**, 1188–1190.
28. Chapco, W., Ashton, N. W., Martel, R. K. B., Antonishyn, N. and Crosby, W. L., *Genome*, 1992, **35**, 569–574.
29. Kambhampati, S., Black, W. C. IV. and Rai, K. S., *J. Med. Entomol.*, 1992, **29**, 939–945.
30. Virk, P. S., Brian, V. F. L., Jackson, M. T. and Newbury, J., *Heredity*, 1995, **74**, 170–179.
31. Hedrick, P., *Genetics of Population*, Jones and Bartlett, CA, 1985, pp. 72–73.
32. Lynch, M. and Milligan, B. G., *Mol. Ecol.*, 1994, **3**, 91–99.
33. Zhou, X., Faktor, O., Applebaum, S. W. and Coll, M., *Heredity*, 2000, **85**, 251–256.

ACKNOWLEDGEMENTS. This research work was supported by DBT, GOI project grants to B.F. We thank the Department of Agricultural Entomology, UAS, Dharwad for providing infrastructure facilities in rearing the larvae and scientists who helped us during our visit to different locations across South India for *H. armigera* collection. We thank Dr K. Chandrashekara, Dr A. R. V. Kumar (UAS, Bangalore) and Dr G. T. Gujar (IARI, New Delhi) for their constant encouragement.

Received 2 January 2004; revised accepted 14 September 2004

B. FAKRUDIN[1,*]
S. H. PRAKASH[1]
K. B. KRISHNAREDDY[1]
VIJAYKUMAR[1]
P. R. BADARI PRASAD[1]
B. V. PATIL[2]
M. S. KURUVINASHETTI[1]

[1]*Institute of Agri-Biotechnology, University of Agricultural Sciences, Krishinagar, Dharwad 580 005, India*
[2]*Department of Agricultural Entomology, College of Agriculture, UAS, Raichur 584 101, India*
**For correspondence.*
e-mail: bfakrudin@hotmail.com

Eco-friendly way to keep away pestiferous Giant African snail, *Achatina fulica* Bowdich from nursery beds

The Andaman and Nicobar Islands in the Bay of Bengal are peaks of a submerged mountain range, arching from Myanmar to Sumatra, between latitudes 6°45′ and 13°41′N and longitudes 92°12′ and 93°57′E. The group comprises over 572 islands and rocks, with a total coastline of about 1962 km. The forest type of the Andaman and Nicobar islands can be broadly classified as tropical evergreen, with inland areas being either forest or grasslands and significant proportion of the coast being mangroves. These islands are home to 5357 species of fauna and 1454 taxa of angiosperms. Of the total species of fauna, 487 are endemic and in flora a total of 221 species are reported to be endemic to these islands.

Some of the invasive pests have invaded and established in these islands. One such pest is the Giant African snail, *Achatina fulica* (Figure 1). It was reportedly introduced during 1940s into Andamans[1]. By 1973, it was reported to have spread to a number of places in both the Andaman and Nicobar Islands[2]. During the same year it was reported that the snails were absent in the recently inhabited islands of Neil, Havelock, Little Andamans and Great Nicobar[3]. Today the snail may be seen in North, Middle, South and Little Andamans, Long Island, Car Nicobar, Katchal, Nancowry and Great Nicobar[4]. This pest is polyphagous, attacking about 225 plants of agricultural and horticultural importance, including cuttings and seedlings. Vegetables belonging to the families Cruciferae, Cucurbitaceae and Leguminoseae are known to suffer the most damage[5]. The Giant African snail is considered a serious pest of nursery beds of vegetables and flower plants. They move out of hideouts at dusk and feed throughout the night ravaging the seedlings.

Chemical control of snails typically employs metaldehyde, methiocarb (Mesurol), salt, or combinations of these chemicals with other molluscicides in a myriad of bait formulations or foliar sprays. The principal toxic effect of metaldehyde is through stimulation of the mucous glands, which cause excessive sliming, leading to death by dehydration. Metaldehyde is toxic to slugs and snails both by ingestion and absorption by the 'foot' of the mollusc. The pesticidal properties of methiocarb are similar to the toxic action of other carbamates which prevent effective nerve transmission by inhibiting the enzyme acetylcholinesterase. In addition to these molluscicides, sodium chloride – common table salt – is an effective dehydrating agent. It may be applied as a 12-inch barrier application on the perimeter of known/suspected snail-infested areas. During periods of rain or high relative humidity, salt barriers should be renewed frequently.

Various molluscicides like metaldehyde are non-selective, thus their use has a chance

Figure 1. *Achatina fulica.*

of endangering the survival of non-target snails, including the endemic fauna. Effective bio-control agents like *Euglandia rosea*, *Gonaxis quadrilateralis* cannot be used as they may lead to destruction of native snails on introduction. Similarly turbullerian flatworm, *Platydemus manokwari* has been reported successful in controlling population of *A. fulica* on the islands of Guam, Bugsuk in Philippines and Maldives[6,7]. Effort to introduce *P. manokwari* to control *A. fulica* is to be discouraged as it has been seriously implicated in the decline of native snails in the Pacific[8].

Among the reasons for the rapid dispersal of *A. fulica* is its high reproductive capacity and lack of seriousness about the importance of quarantine. *A. fulica* generally occurs in dense populations in urban areas where it attacks ornamental gardens, vegetable gardens, and small-scale agriculture. All the methods for management having failed, there was a need to search for botanical, eco-friendly molluscicides, which would kill, repel the pest so that it could be integrated with other management practices to suppress the pest to afford protection to vegetables.

During 2002, in the Garacharma farm of Central Agricultural Institute it was noticed that cuttings of Alligator apple, *Annona glabra* L. were untouched by *A. fulica*[9]. After this observation, studies were undertaken to use them as a snail repellent to protect the nursery beds that are damaged by *A. fulica*.

Softwood cuttings of *Annona glabra* L., *Annona reticulata* L., *Annona muricata* L., *A. squamosa* L., *Averrhoea bilimbi* L., *Averrhoea carambola* L. and *Moringa pterigosperma* L. measuring 15 cm in length and ten mm in dia. were collected. These cuttings were radially arranged in acrylic cages ($1.5'' \times 1.5'' \times 1.5''$). Field-collected *A. fulica* weighing in the range of 40–50 g were starved for 48 h and these were released 1 per cage in center for choice test. A total of 10 replications were maintained. Observation on the area of bark fed by *A. fulica* was recorded after 48 h of exposure.

To confirm the results of choice test under field conditions, nursery beds of dimension 1 m × 1 m were raised and seeds of African marigold, *Tagetes erecta* L. were sown, as it is one of the most preferred host of *A. fulica*. Along the perimeter of nursery bed, soft wood cuttings of *A. glabra*, *A. reticulata*, *A. muricata*, *A. squamosa*, *A. bilimbi*, *A. carambola* and *M. pterigosperma* were planted with a spacing of 0.5 cm between cuttings. The height of cuttings from ground level was maintained at 10 cm. When the seedlings of *T. erecta* were 7 days old, a 5 cm-wide common salt bund was made at a distance of 15 cm from periphery of nursery bed to avoid outward movement of *A. fulica*. Ten field-collected *A. fulica* weighing in range of 40–50 gm were starved for 48 h and released in between periphery of nursery bed and salt bund at 1900 h. Totally three replications were maintained. After 12 h of exposure, data were collected on number of snails invading the fence made up of cuttings.

The result of the choice test indicated that *M. pterigosperma* was the most preferable among the cuttings put to test, recording the maximum area fed (47.14 cm^2). The cuttings of *A. glabra* were significantly protected from snail, being totally untouched (Table 1). To some extent the other members of Annonaceae were not readily preferable. The two members of Oxalidaceae family, *A. carambola*, *A. bilimbi* were fed to the extent of 34.28 and 31.64 cm^2. To confirm the repellent and antifeedent activity of *A. glabra* against *A. fulica*, all the cuttings were planted closely as a fence around *T. erecta* nursery bed. It was noticed that *A. glabra* totally kept the nursery bed free from *A. fulica*, followed by *A. muricata*, *A. reticulata* and *A. squamosa*, which repelled the snails from gaining entry, but there was no mortality of snails due to *A. glabra*. The results of the choice test were closely correlated with repellent test. All the snails released gained entry into nursery beds lined by *M. pterigosperma*, which happens to be a favourable host. The members of Oxalidaceae were also not effective in deterring *A. fulica* from gaining entry into fenced area (Table 2). The annonacin found in *A.*

Table 1. Mean area of softwood bark of different species fed by *A. fulica*

Species	Area of bark fed after 48 h (cm^2)*
Annona muricata	8.43[b]
Annona glabra	0[a]
Annona squamosa	12.26[b]
Annona reticulata	9.28[b]
Averhoea carambola	34.28[c]
Averhoea bilimbi	31.64[c]
Moringa pterigosperma	47.14[d]

*Mean of 10 replications.
Mean followed by same letter is not significantly different from other by LSD ($P = 0.01$).

Table 2. Mean number of *A. fulica* invading softwood fence of different species surrounding nursery beds of *T. erecta*, 12 h after exposure

Species	Mean no. of *A. fulica* invading nursery beds*
Annona muricata	3.66[b]
Annona glabra	0[a]
Annona squamosa	5.0[b]
Annona reticulata	4.33[b]
Averhoea carambola	8.0[c]
Averhoea bilimbi	8.66[c]
Moringa pterigosperma	10.0[d]

*Mean of three replications.
Mean followed by same letter is not significantly different from other by LSD ($P = 0.01$).

glabra[10] may be the compound, which repelled *A. fulica* from gaining entry to nursery bed. Ethanolic extracts from various parts of *A. crassiflora*, *A. glabra*, *A. muricata* and *A. squamosa* have been reported to demonstrate molluscicidal and ovicidal properties against *Biomphalaria glabrata*[11].

One of the advantages of *A. glabra* is that the cuttings sprout when planted and they can be constantly trimmed to maintain a live fence around the nursery beds to ward off the Giant African snail from gaining entry into nursery bed. Owing to high and unpredictable rainfall, application of conventional metaldehyde is not feasible as it gets washed away. It also affects other non-target endemic species of snails and contaminates the fragile ecosystem. Therefore, this method of erection of *A. glabra* softwood cutting fence is a feasible and practically applicable alternative to save nursery beds from the menace of *A. fulica*.

1. Whitaker, R., *Endangered Andamans*, Department of Environment, India, 1985.
2. Srivastava, P. D., *Pesticides*, 1970, **4**, 92–96.
3. Srivastava, P. D. and Abbas, S. R., *Entomol. Newsl.*, 1973, **3**, 36.
4. Tikader, B. K. and Das, A. K., *Glimpses of Animal Life of Andaman and Nicobar Islands*, ZSI, Calcutta, 1985.
5. Mead, A. R., *The Giant African Snail: A Problem in Economic Malacology*, Univ. of Chicago Press, 1961.
6. Muniappan, R., *Alafua Agric. Bull.*, 1983, **8**, 43–46.
7. Muniappan, R., *FAO Plant Prot. Bull.*, 1987, **35**, 127–133.
8. Hopper, D. R. and Smith, B. D., *Pac. Sci.*, 1992, **46**, 77–85.
9. Singh, D. R., Medhi, R. P., Senani, S., Senthil Kumar, R. and Rai, R. B., *The Alligator Apple*, Folder Published by Director, CARI, Port Blair, 1961.
10. Dos Santos, A. F. and Sant Ana, A. E., *Phytomedicine*, 2001, **8**, 115–120.
11. Gallardo, T., Aragon, R., Tormo, J. R., Blazquez, M. A., Zafra-Polo, M. C. and Cortes, D., *Phytochemistry*, 1998, **47**, 811–816.

ACKNOWLEDGEMENTS. We thank Dr R. B. Rai, Director, CARI, for his constant encouragement.

G. SHYAM PRASAD*
D. R. SINGH
S. SENANI
R. P. MEDHI

Central Agricultural Research Institute, Port Blair 744 101, India
**For correspondence.*
e-mail: spgogineni@rediffmail.com