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The host and geographical range of the grasshopper pathogen *Paranosema (Nosema) locustae* revisited

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Abstract

Host and geographical ranges are updated for the microsporidium *Paranosema locustae*; this pathogen was developed in the USA as a long-term microbial control agent of grasshoppers. Currently known to be susceptible to *P. locustae*, either naturally or experimentally, are 121 species of Orthoptera from North and South America, Africa, Australia, China, and India. Most belong to the Acrididae (112), and within this family, to the Melanoplinae (36), Oedipodinae (35), and Gomphocerinae (35). The host range of *P. locustae*, as presently understood, is based largely on morphology and could change if molecular techniques revealed cryptic species. The North American isolate is not only the best studied, but the one established after its introduction into Argentina, and produced and used in China: it can be considered a generalist pathogen. As such, *P. locustae* may have the ability to alter, through differences in host susceptibilities, the structure of grasshopper assemblages in areas where it was not present before. Long-term careful monitoring of key grasshopper species in areas of pathogen introduction/establishment may reveal such effects.

Introduction

Paranosema locustae is a spore-forming pathogen of the adipose tissue of orthopterans that was isolated, selected, and developed in the USA as a long-term microbial control agent of grasshoppers (Henry & Oma 1981, Johnson 1997, Lockwood *et al.* 1999). *P. locustae* belongs to the Microsporidia, a group of unicellular eukaryotes that are obligate intracellular parasites of animals and some protists (Wittner & Weiss 1999). Microsporidia were historically regarded as Protozoa or Archezoa, but recent studies at the molecular level have shown they are actually related to Fungi (Keeling & Fast 2002).

In North America, Steinhaus (1951) first noticed *P. locustae*, albeit without naming it, in 3 species of grasshoppers of the genus *Melanoplus* from Montana. Soon after, Canning (1953) described *P. locustae* as *Nosema locustae*, using diseased African migratory locusts, *Locusta migratoria migratorioides*, from a rearing colony at the Imperial College Field Station in London. Sokolova *et al.* (2003), while erecting the new genus *Paranosema* for another microsporidian pathogen of Orthoptera from the cricket *Gryllus bimaculatus*, transferred *N. locustae* to *Paranosema*, based on molecular and ultrastructural grounds, erecting the new combination *P. locustae*. Even more recently, Slamovits *et al.* (2004) proposed another new combination, *Antonospora locustae*; but Sokolova *et al.* (2005) provided reasons for favoring the name *P. locustae*.

One of several factors that permitted the selection of *P. locustae* for its development as a microbial control agent, is its wide host range among acridomorphs. While the host range of most Microsporidia is relatively narrow (Solter *et al.* 2005), host specificity is a species-based character in Microsporidia, that should be considered individually (Solter & Becnel 2003). The unusually broad host range

of *P. locustae* was observed early in its development as a biocontrol agent (Henry 1969), and judged to be desirable (Henry 1977). This was because many grasshopper species are considered pests, and frequently, when outbreaks occur, more than one (and sometimes several) species are involved.

Henry (1969) provided the first list of hosts that he knew to be susceptible, which included 55 North American species, 53 of them acridomorphs, one cricket, and one tetrigid. Almost 2 decades later, Brooks (1988) presented a new list of worldwide susceptible insects, all of them Orthoptera, expanding the known host range of *P. locustae* to 95 species. Since then, additional work has been conducted on *P. locustae*, much of it outside of North America, in Argentina, China and South Africa. The present update compiles the current available knowledge on the host and geographical range of *P. locustae*. Caution should be exerted when assessing the currently known host range of *P. locustae* because it is largely based on morphological grounds. The possibility that a scrutiny of different isolates at the molecular level could reveal the occurrence of cryptic species cannot be ruled out.

Host range and distribution

Table 1 shows, by continent, family, and subfamily, all the species reported to be susceptible, either naturally or experimentally, to *P. locustae*, which at present total 121. Of these, 112 species are Acrididae, and the remaining 9 susceptible species belong to the families Romaleidae (3), Gryllidae (1), Oecanthidae (1), Tettigidae (1), Tettigoniidae (1), and Pyrgomorphidae (2). Among the Acrididae, susceptible species are in the subfamilies Acridinae (2), Calliptaminae (1), Catantopinae (2), Cyrtacanthacridinae (5), Copiocerinae (1), Eyprepocnemidae (3), Gomphocerinae (23), Melanoplinae (36), Oedipodinae (35), Oxyinae (3), and Tropidopolinae (1). Based on the host species involved in the natural infections (ecological host range, Solter *et al.* 2005), on the natural and induced (after field applications) prevalences, the results of laboratory bioassays (physiological host range, Solter *et al.* 2005), and on the intensity of infections (spore loads per individual), it appears that species in the subfamilies Melanoplinae, Oedipodinae, and Gomphocerinae are generally more susceptible than species in other subfamilies (Canning 1953; Henry 1969; Henry *et al.* 1973; Ewen 1983; Lockwood 1988; Whitlock & Brown 1991; Bomar *et al.* 1993; Wang & Yu 1994; Yuhua 1997; Lange 2003 a, b). It is important to note that in the earlier literature on host range of *P. locustae* (Henry 1969), most species that by then were treated as Cyrtacanthacridinae are now considered to be within the Melanoplinae.

P. locustae has been reported to be native in North America, India and South Africa (Henry 1969, Ewen 1983, Srivastava & Bhanotar 1985, Raina *et al.* 1987, Whitlock & Brown 1991). It has been mentioned for the Irkutsk region of Russia (Issi & Lipa 1968), but later apparently treated by Issi & Krylova (1987) as a different species, *Nosema chorthippi*. However, aside from the original description by Canning (1953), virtually all available knowledge on *P. locustae* comes from research on the North American isolate, while the records for India were poorly diagnosed.

The North American isolate of *P. locustae* has become established after its introduction in the Pampas of Argentina (Sokolova & Lange 2002, Lange 2003a, Lange & De Wysiecki 2005), and it is produced and used in China for the control of grasshoppers and locusts (Long 1995, Wangpeng *et al.* 2001, Shi & Njaqi 2004). Unfortunately, the fate of introductions conducted in other countries, such as Australia, Cape Verde, Mali, Niger, and Mauritania has not been explored.

The present update shows the significant, relatively recent, expansion in host and geographical ranges of *P. locustae*, mostly as a result of applied use. Due to the extremely wide host range acknowledged at present for *P. locustae*, this microsporidium clearly qualifies as a generalist pathogen. In assessing the significance of this, those infections recorded in field-collected individuals, either naturally (labeled as N in Table 1), or as induced infections following an introduction or augmentation event (labeled as I and A in Table 1), are of particular relevance. Although the physiological host range can be used as an indicator of ecological host range, it needs to be carefully observed and evaluated. When forced into experimental hosts during bioassays, some microsporidia are known to develop atypical infections that are not likely to occur or persist in the field (Solter *et al.* 2005).

A generalist pathogen has the ability to alter, through differences in host susceptibilities, the structure of insect assemblages when established in areas where it was not present before (Bonsall 2004). In this sense, regular, long-term monitoring in grasshopper communities of Argentina and China should prove very informative in the long run. Key grasshopper species, in terms of known or potential susceptibility, rareness, and range of geographical distribution, should be designated within areas of pathogen establishment and surroundings. Careful attention should be paid in future surveys to their populations and eventual infection status.

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References

Bomar Ch.R., Lockwood J.A., Pomerinke M.A, French J.D. 1993. Multiyear evaluation of the effects of *Nosema locustae* (Microsporidia: Nosematidae) on rangeland Grasshopper (Orthoptera: Acrididae) population density and natural biological controls. *Environmental Entomology* 22: 489-497.

Bonsall M.B. 2004. The impact of diseases and pathogens on insect population dynamics. *Physiological Entomology* 29: 223-236.

Brooks W.M. 1988. Entomogenous Protozoa, pp. 1-149. In: Ignoffo, C.M. (Ed.), *Microbial Insecticides*, Vol. 5, Handbook of naturally occurring pesticides. CRC, Boca Raton.

Canning E.U. 1953. A new microsporidian, *Nosema locustae* n. sp., from the fat body of the African migratory locust, *Locusta migratoria migratorioides*. *Parasitology* 43: 287-290.

Canning E.U. 1962. The life cycle of *Nosema locustae* Canning in *Locusta migratoria migratorioides*, and its infectivity to other hosts. *Journal of Invertebrate Pathology* 4: 237-247.

Ewen A.B. 1983. Extension of the geographic range of *Nosema locustae* (Microsporida) in grasshoppers (Orthoptera: Acrididae). *The Canadian Entomologist* 115: 1049-1050.

Habtwold T., Landin J., Wennergen U., Bergman K.O. 1995. Life table for the tef grasshopper, *Aiolopus longicornis* under laboratory conditions and demographic effects of the pathogen *Nosema locustae*. *Biological Control* 5: 497-502.

Henry J.E. 1969. Extension of the host range of *Nosema locustae* in Orthoptera. *Annals of the Entomological Society of America* 62: 452-453.

Henry J.E. 1971. Experimental application of *Nosema locustae* for control of grasshoppers. *Journal of Invertebrate Pathology* 18: 389-394.

Henry J.E. 1977. Development of microbial agents for the control of Acrididae. *Revista de la Sociedad Entomologica Argentina* 36: 125-134.

Henry J.E., Oma E.A. 1974. Effect of prolonged storage of spores on field applications of *Nosema locustae* (Microsporidia: Nosematidae) against grasshoppers. *Journal of Invertebrate Pathology* 23: 371-377.

Henry J.E., Oma E.A. 1981. Pest control by *Nosema locustae*, a pathogen of grasshoppers and crickets, pp. 573-585. In: Burges D. (Ed.) *Microbial control of pests and plant diseases 1970-1980* Academic Press, New York.

Henry J.E., Onsager J.A. 1982. Experimental control of the Mormon cricket, *Anabrus simplex*, by *Nosema locustae* (Microsporidia: Nosematidae), a protozoan parasite of grasshoppers (Orthoptera: Acrididae). *Entomophaga* 27: 197-201.

Henry J.E., Tiaht K., Oma E.A. 1973. Importance of timing, spore concentrations, and levels of spore carrier in applications of *Nosema locustae* (Microsporidia: Nosematidae) for control of grasshoppers. *Journal of Invertebrate Pathology* 21: 23-272.

Henry J.E., Fowler J.L., Wilson M.C., Onsager J.A. 1985. Infection of West African grasshoppers with *Nosema locustae* (Protozoa: Microsporida: Nosematidae). *Tropical Pest Management* 31: 144-147.

Issi I.V., Lipa J.J. 1968. Report on identification of Protozoa pathogenic for insects in the Soviet Union (1961-1966), with descriptions of some new species. *Acta Protozoologica* 6: 281-291.

Issi I., Krylova S.V. 1987. Locusts microsporidia. In: Shumakov E.M. (Ed.) *Locusts, ecology and control methods. Proceedings All-Union Institute for Plant Protection St. Petersburg* 58-62 (In Russian).

Johnson D.L. 1997. Nosematidae and other Protozoa as agents for the control of grasshoppers and locusts: current status and prospects. *Memoirs of the Entomological Society of Canada* 171: 375-389.

Keeling P.J., Fast N.M. 2002. Microsporidia: Biology and evolution of highly reduced intracellular parasites. *Annual Reviews of Microbiology* 56: 93-116.

Lange C.E. 2002. El desarrollo de *Nosema locustae* Canning (Protozoa: Microsporidia) para el control biológico de tucuras (Orthoptera: Acridoidea) y las consecuencias de su utilización en la Argentina. *Revista de la Sociedad Entomologica Argentina* 61: 1-9.

Lange C.E. 2003a. Long-term patterns of occurrence of *Nosema locustae* Canning and *Perezia dichroplusae* Lange (Microsporidia) in grasshoppers (Orthoptera: Acrididae) of the Pampas, Argentina. *Acta Protozoologica* 42: 309-315.

Lange C.E. 2003b. Niveles de esporulación experimentales y naturales del agente de biocontrol *Nosema locustae* (Microsporidia) en especies de tucuras y langostas (Orthoptera: Acridoidea) de la Argentina. *Revista de la Sociedad Entomologica Argentina* 62: 15-22.

Lange C.E., De Wysiecki M.L. 2005. Espectro hospedador, prevalencias y dispersion del entomopatógeno *Paranosema locustae* (Microsporidia) en tucuras (Orthoptera: Acridoidea) del Sudeste de Buenos Aires. *Revista de Investigaciones Agropecuarias* 34: 129-143.

- Lange C.E., Sanchez N.E., Wittenstein E. 2000. Effect of the pathogen *Nosema locustae* (Protozoa: Microspora) on mortality and development of nymphs of the South American locust, *Schistocerca gregaria* (Orthoptera: Acrididae). *Journal of Orthoptera Research* 9: 77-80.
- Liu W.X., Yan Y.-H. 2000. A preliminary investigation on sustainable management of *Oxya chinensis* (Thunb.) mainly with biological agents. *Acta Entomologica Sinica* 43: 186-190.
- Lockwood J.A. 1988. Biology and recommendations for the use of *Nosema locustae* Canning: a biological control agent of grasshoppers. Wyoming Agriculture Experiment Station Bulletin B-917.
- Lockwood J.A., Bomar C.R., Ewen A.B. 1999. The history of biological control with *Nosema locustae*: lessons for locust management. *Insect Science and Applications* 19: 333-350.
- Long Z. 1994. Epizootic and transmission of *Nosema locustae* in the populations of grasshoppers and locusts. Ph.D. Thesis, Dept Plant Protection, Beijing Agricultural University, Beijing.
- Long Z. 1995. A preliminary survey on the epizootics of infection of *Nosema locustae* among grasshoppers in rangeland. *Acta Agrestia Sinica*, 3: 223-229.
- Long Z., Wangpeng S., Yuhua Y., Boneng L., Manfeng W., Shuimei Y., Deqing L. 2001. Relationships between application rate of *Nosema locustae* and infection of *Locusta migratoria manilensis* in Hainan province. *Journal of China Agricultural University* 6: 90-95.
- Luna G.C., Henry J.E., Ronderos R.A. 1981. Infecciones experimentales y naturales con protozoos patógenos en acridios de la Republica Argentina. *Revista de la Sociedad Entomologica Argentina* 40: 243-247.
- Ma D.S., Bai S.L., Li Z.H. 2005. Studies on sustainable controlling rangeland grasshoppers with *Nosema locustae* in Chaidamu of Qinghai province. *Natural Science Version* 36: 199-204.
- Moulden J. 1981. Disease could control grasshoppers. *Journal of Agriculture*, 22: 53-54.
- Raina S.K., Rai M.M., Khurad A.M. 1987. Grasshopper and locust control using microsporidian insecticides, pp.345-365. In: Maramorosch K. (Ed.) *Biotechnology in Invertebrate Pathology and Cell Culture*, Academic Press, New York.
- Raina S.K., Das S., Rai M.M., Khurad A.M. 1995. Transovarial transmission of *Nosema locustae* (Microsporidia: Nosematidae) in the migratory locust *Locusta migratoria migratorioides*. *Parasitology Research* 81: 38-44.
- Shi W.P., Njaqi P.G.N. 2004. Disruption of aggregation behaviour of Oriental migratory locusts (*Locusta migratoria manilensis*) infected with *Nosema locustae*. *Journal of Applied Entomology* 128: 414-418.
- Slamovits C.S., Williams B.A.P., Keeling P.J. 2004. Transfer of *Nosema locustae* (Microsporidia) to *Antonospora locustae* n. com. based on molecular and ultrastructural data. *Journal of Eukaryotic Microbiology*, 51: 207- 213.
- Sokolova J., Lange C.E. 2002. An ultrastructural study of *Nosema locustae* Canning (Microspora) from three species of Acrididae (Orthoptera). *Acta Protozoologica* 41: 221-237.
- Sokolova Y.Y., Dolgikh V.V., Morzhina E.V., Nassonova E.S., Issi I.V., Terry R.S., Ironside J.E., Smith J.E., Vossbrinck C.R. 2003. Establishment of the new genus *Paranosema* based on the ultrastructure and molecular phylogeny of the type species *Paranosema grylli* gen. nov., comb. nov., from the cricket *Gryllus bimaculatus*. *Journal of Invertebrate Pathology* 84: 159-172.
- Sokolova Y.Y., Issi I.V., Morzhina E.V., Tokarev Y.S., Vossbrinck C.R. 2005. Ultrastructural analysis supports transferring *Nosema whitei* Weiser 1953 to the genus *Paranosema* and creation [of] a new combination, *Paranosema whitei*. *Journal of Invertebrate Pathology*, 90: 122-126.
- Solter L.F., Becnel J.J. 2003. Environmental safety of Microsporidia, pp. 93-118. In: Hokkanen H, Hajek A. (Eds) *Environmental Impacts of Microbial Insecticides*. Kluwer Academic Publishers, Netherlands.
- Solter L.F., Maddox J.V., Vossbrinck C.R. 2005. Physiological host specificity: a model using the European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae) and microsporidia of row crop and other stalk-boring hosts. *Journal of Invertebrate Pathology* 90: 127-130.
- Srivastava Y.N., Bhanotar R.K. 1985. A new record of a protozoan, *Nosema locustae* Canning infecting desert locusts from Rajasthan. *Indian Journal of Entomology* 45: 500-501.
- Steinhaus E.A. 1951. Report on diagnoses of diseased insects 1944-1950. *Hilgardia* 20: 629-678.
- Wang L., Yu X. 1994. The mass production and application of *Nosema locustae* against grasshoppers. *Acta Agrestia Sinica* 2: 49-54.
- Wangpeng S., Yan Y., Zhu E., Zhang W. 2001. Sustainable management of locust *Locusta migratoria manilensis* using *Nosema locustae* in Hainan Province. *Journal of Plant Protection* 28: 207-212.
- Whitlock V.H., Brown S.T. 1991. First record for *Nosema locustae* in the Brown locust *Locustana pardalina* in South Africa, and the yield of spores in laboratory bioassays. *Journal of Invertebrate Pathology* 58: 164-167.
- Wittner M., Weiss L.M. (Eds) 1999. *The Microsporidia and Microsporidiosis*. American Society of Microbiology Press, Washington, D.C.
- Yu-hua Y. 1997. The sustainable management of grasshoppers and locusts in China. *Metaleptea* (The Orthopterists' Newsletter) 17: 17.
- Zang J., Cao J., Li G., Li Ch., Yan Y. 2001. Biological control of *Oxya chinensis* by using *Nosema locustae*. *Chinese Journal of Biological Control* 17: 126-128.

Table 1. Species of Orthoptera, by continent, family, and subfamily, known to be susceptible to *Paranosema locustae*. (N) natural infection in a wild host, (I) infection in a wild host after an introduction event of the pathogen, (E) experimental infection resulting from a laboratory bioassay, (S) spontaneous infection in a host rearing facility, (A) infection in a wild host after application in a general area where *Paranosema locustae* is known to be native.

Geographic distribution, family, subfamily, species, and infection type	References
North America (western USA, southern Canada)	
Acrididae	
Cyrtacanthacridinae	
<i>Schistocerca americana</i> (E), <i>S. nitens</i> (= <i>vaga</i>) (E)	Henry 1969
Gomphocerinae	
<i>Aeropedellus clavatus</i> (N), <i>Ageneotettix deorum</i> (N), <i>Amphitornus coloradus</i> (A), <i>Aulocara ellioti</i> (N), <i>Aulocara</i> (= <i>Depranopterna</i>) <i>femoratum</i> (A), <i>Bruneria brunnea</i> (N), <i>Chorthippus curtipennis</i> (N), <i>Cordillacris occipitalis</i> (A), <i>Mermiria bivittata</i> (N), <i>Opeia obscura</i> , (N), <i>Phlibostroma quadrimaculatum</i> (N), <i>Psoloessa delicatula delicatula</i> (N)	Henry 1969, Ewen 1983, Henry 1971, Henry & Oma 1974,
Melanopliinae	
<i>Bradynotes obesa</i> (N), <i>Hesperotettix viridis viridis</i> (N), <i>Hypochlora alba</i> (E), <i>Melanoplus alpinus</i> (N), <i>M. bivittatus</i> (N), <i>M. borealis borealis</i> (N), <i>M. bowditchi canus</i> (E), <i>M. confusus</i> (N), <i>M. cuneatus</i> (N), <i>M. dawsoni</i> (N), <i>M. differentialis</i> (N), <i>M. femurrubrum</i> (N), <i>M. foedus foedus</i> (N), <i>M. gladstoni</i> (E), <i>M. infantilis</i> (N), <i>M. keeleri luridus</i> (E), <i>M. lakinus</i> (A), <i>M. occidentalis</i> (N), <i>M. packardii</i> (N), <i>M. sanguinipes sanguinipes</i> (N), <i>Oedaleonotus enigma</i> (N), <i>Phoetaliotes nebrascensis</i> (N),	Henry 1969, Steinhaus 1951, Ewen 1983, Henry & Oma 1974, Bomar <i>et al.</i> 1993
Oedipodinae	
<i>Arphia conspersa</i> (N), <i>A. pseudonietana</i> (E), <i>Camnula pellucida</i> (N), <i>Conozoa wallula</i> (N), <i>Cratypedes neglectus</i> (N), <i>Dissosteira carolina</i> (N), <i>D. spurcata</i> (N), <i>Encoptolophus costalis</i> (E), <i>Hadrotettix trifasciatus</i> (N), <i>Metator nevadensis</i> (N), <i>M. pardalinius</i> (N), <i>Spharagemon equale</i> (A), <i>S. collare</i> (A), <i>Trachyrhachys kiowa</i> (N), <i>Trimerotropis sp.</i> (N), <i>T. fontana</i> (N), <i>T. gracilis</i> (N), <i>T. inconspicua</i> (N), <i>T. latifasciata</i> (= <i>laticinta</i>) (N), <i>T. pallidipennis</i> (N), <i>Xanthippus corallipes</i> (N)	Henry 1969, Ewen 1983, Canning 1962, Henry <i>et al.</i> 1973, Bomar <i>et al.</i> 1993
Romaleidae	
Romaleinae	
<i>Brachystola magna</i> (N)	Henry 1969
Gryllidae	
Gryllinae	
<i>Gryllus sp.</i> (E)	Henry 1969
Oecanthidae	
Oecanthinae	
<i>Oecanthus sp.</i> (A)	Bomar <i>et al.</i> 1993
Tetrigidae	
Undetermined sp. (E)	Henry 1969
Tettigoniidae	
Tettigoniinae	
<i>Anabrus simplex</i> (N)	Henry & Onsager 1982
South America (western Pampas and northwestern Patagonia, Argentina)	
Acrididae	
Acridinae	
<i>Allotruxalis gracilis</i> (I)	Lange 2003a
Cyrtacanthacridinae	
<i>Schistocerca cancellata</i> (E)	Lange <i>et al.</i> 2000, Sokolova & Lange 2002, Lange 2003b
Copiocerinae	
<i>Aleuas lineatus</i> (E)	Luna <i>et al.</i> 1981
Gomphocerinae	
<i>Euplectrotettix schulzi</i> (I), <i>Laplatacris dispar</i> (E), <i>Rhammatocerus pictus</i> (I), <i>Staurorhectus longicornis</i> (I)	Lange 2003a, Luna <i>et al.</i> 1981
Melanopliinae	
<i>Baeacris punctulatus</i> (I, E), <i>B. pseudopunctulatus</i> (I, E), <i>Dichroplus conspersus</i> (E), <i>D. elongatus</i> (I, E), <i>D. maculipennis</i> (I, E), <i>D. pratensis</i> (I), <i>D. schulzi</i> (E), <i>D. vittatus</i> (I), <i>Leiotettix pulcher</i> (I), <i>Neopedies brunneri</i> (I), <i>Ronderosia bergi</i> (E), <i>R. forcipata</i> (I), <i>Scotussa daguerrei</i> (I), <i>S. lemniscata</i> (I)	Lange 2002, Lange 2003a,b; Luna <i>et al.</i> 1981 Sokolova & Lange 2002
Oedipodinae	
<i>Trimerotropis pallidipennis</i> (E)	Lange, unpublished results
Romaleidae	
Romaleinae	
<i>Diponthus argentinus</i> (I), <i>Zoniopoda tarsata</i> (I)	Lange 2003a

Asia (Rajasthan and Vidarbha, India; Inner Mongolia, Hainan and Qinghai, China)**Acrididae****Cyrtacanthacridinae***Schistocerca gregaria* (N)

Srivastava & Bhanotar 1985

Gomphocerinae*Chorthippus fallax* (I), *Chorthippus* sp. (I), *Myrmeleotettix palpalis* (I), *Dasyhippus barbipes* (I), *Gomphocerus licenti* (I)Long 1994, Ma *et al.* 2005**Oedipodinae***Angaracris rhodopa* (I), *A. barabensis* (I), *Bryodema luctuosum luctuosum* (I), *Locusta migratoria manilensis* (E, I), *Oedaleus asiaticus* (I)Long 1994, Wang & Yu 1994; Yuhua 1997 Long 1994, Long *et al.* 2001, Raina *et al.* 1995, Shi & Njaqi 2004, Ma *et al.* 2005**Oxyinae***Hieroglyphus* sp. (N), *Oxya chinensis* (I)Raina *et al.* 1987, Liu & Yan 2000, Zang *et al.* 2001**Australia (laboratory production)****Acrididae****Cyrtacanthacridinae***Valanga irregularis* (E)

Moulden 1981

Europe (locust rearing facilities in England)**Acrididae****Cyrtacanthacridinae***Schistocerca gregaria* (S)

Canning 1953, 1962

Oedipodinae*Locusta migratoria migratorioides* (S)

Canning 1953, 1962

Africa (Karoo, South Africa)**Acrididae****Acridinae***Acrida bicolor* (E)Henry *et al.* 1985**Calliptaminae***Acorypha glaucopsis* (E)Henry *et al.* 1985**Catantopinae***Cryptocatantops haemorrhoidalis* (E), *Diabolocatantops axillaris* (I, E)Henry *et al.* 1985**Eyprepocnemidinae***Cataloipus cymbiferus* (E), *Cataloipus fuscocerulipes* (I, E), *Heteracris haterti* (E)Henry *et al.* 1985**Gomphocerinae***Krassauria amabile* (E), *K. angulifera* (E)Henry *et al.* 1985**Oedipodinae***Acrotylus longipes* (I, E), *Aiolopus longicornis* (E), *A. simulatrix* (E), *Locustana pardalina* (N), *Oedaleus nigeriensis* (I, E), *O. senegalensis* (I, E), *Pseudosphingonotus savignii* (I, E), *Sphingonotus canariensis* (I, E)Henry *et al.* 1985, Habtewold *et al.* 1995, Whitlock & Brown 1991**Oxyinae***Hieroglyphus daganensis* (E)Henry *et al.* 1985**Tropidopolinae***Homoxyrhopes punctipennis* (E)Henry *et al.* 1985**Pyrgomorphidae****Pyrgomorphinae***Pyrgomorpha cognata* (I, E), *Zonocerus variegatus* (E)Henry *et al.* 1985