Yelseti Ramachandra Rao's contribution to entomology and his pioneering work on the management of invasive plant species in India

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Yelseti Ramachandra Rao (YRR) was one of the founding scientists responsible for laying a strong foundation for scientific entomology in India. After obtaining a Master's degree in 1906, he worked on various aspects of entomology. Until 1930, he extensively worked on various insect groups of economic importance in the Madras Presidency (presently Tamil Nadu, some segments of modern Andhra Pradesh, Kerala and Karnataka) with two short breaks. In 1920 when the understanding of biological control of weeds was limited, YRR published his pioneering work on Lantana camara and several other weedy plants. Later in 1930, he started his work on Schistocerca gregaria (Orthoptera: Acrididae) and published a report in 1960, which led to the establishment of the Locust Warning Organization, Karachi (undivided India).

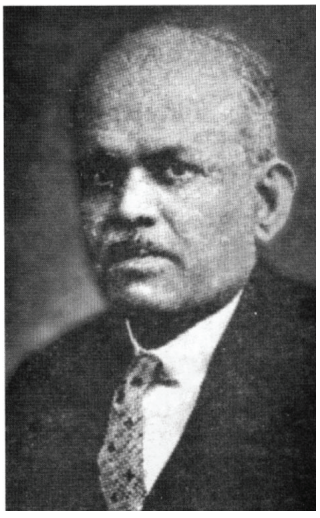
'During the last decade, locusts have, in many parts of the world, been so much in the limelight that they hardly stand in need of introduction. During the years 1929 and 1930 especially, there were not many days on which mention was not made of them in the Indian Dailies, either in regard to their flights or the damage done by them to crops. Nor are locusts to be counted as one of the recent upheavals of the modern age. Their history apparently goes back to hoary antiquity. They are mentioned in the Bible, and formed one of the plagues of ancient Egypt. In early Sanskrit literature, references are made to them as one of the recognised calamities of the people. The immensity of the swarms, whose countless myriads often form clouds hiding the sun from the face of the earth, the dramatic suddenness of their appearance, and the terrible severity of their onslaughts, have all combined to infuse a feeling of helplessness and awe in the mind of primitive man, with the result that incursions of locusts have from time immemorial been considered to be of the nature of an act of God.'

– Y. Ramachandra Rao
Current Science, 1935

The above paragraph provides a glimpse of our understanding of the desert locust *Schistocerca gregaria* (Orthoptera: Acrididae) situation in India in 1935, when Yelseti Ramachandra Rao (hereafter YRR) was involved in locust research as the Locust Research Entomologist with the Imperial Council of Agricultural Research (ICAR) station in Karachi (now in Pakistan). Recently, as the Indian subcontinent suffered a major invasion of the desert locust[1], we realize and appreciate the intensity and magnitude of the work of YRR, which is trailblazing, monumental and relevant[2–9].

YRR could be counted along with Ramakrishna Ayyar, Harold Maxwell-Lefroy, and Thomas Bainbrigge Fletcher, who laid a strong foundation for scientific entomology in India, nearly a century ago[10]. YRR was born on 11 September 1885 at Yemmiganur in the Adoni taluk (formerly Bellary district of the Madras Presidency; now in Kurnool district, Andhra Pradesh). He obtained his Bachelor's degree from the Madura College, Madurai in 1903 and Master's degree in Zoology from the Madras Christian College, Madras (now Chennai) in 1906. YRR's significant contributions to various aspects of entomology from 1906 to 1949 are briefly described in this note. He joined the Madras Agricultural Department as an Assistant and worked with the then Government Botanist, Charles Alfred Barber. YRR trained with Maxwell-Lefroy at the Imperial Agricultural Research Institute, Pusa, Bihar[11] and subsequently with Fletcher, who was Madras Government Entomologist (1909–1911)[12]. From 1906 to 1916, he worked at the Agricultural College, Coimbatore, on different aspects of economic entomology and wrote some sections in the book *Some South Indian Insects* by Fletcher[13].

From November 1919 to December 1920, at the request of the Government of Iraq, YRR accepted an assignment to set up entomological research in Baghdad, Iraq (known as Mesopotamia until 1921). He published a paper entitled 'A preliminary list of insect pests of Iraq'[14], which has become a primary source of entomological literature in modern Iraq. YRR returned to India in 1921 and continued work at the Agricultural College in Coimbatore. He published more than 30 papers on the biological control of various pestiferous insects[11]. From December 1930 to March 1939, he served at ICAR, Karachi and participated in the studies on *S. gregaria* in northwestern India. During this posting, he was the Locust Entomologist at Quetta, Balochistan (now in Pakistan; between December 1930 and March 1933) and the Deputy Locust Research Entomologist in Karachi (between April 1933 and February 1939). In 1939, ICAR assigned him the task of writing his comprehensive locust work, which was published in 1960, 13 years after India's independence. YRR formally retired in 1941 and was re-employed from 1946 to 1949 as the Deputy Director of Foreign Quarantines at



Potrait of Yelseti Ramachandra Rao (source: late Dr B. R. Subba Rao).

the Directorate of Plant Protection, Quarantine and Storage, Government of India[9,11]. Major contributions of YRR involved pioneering and extensive work on the biological control of many weedy plants and locust bionomics and ecology, elaborated in the following paragraphs.

Invasives alien species recognition and management

Some plant species reach new exotic environments and because of the absence of natural enemies that keep their populations regulated in their native ranges, they become nuisance organisms, generally termed as 'weeds'. Biological control is an environment-friendly strategy to manage populations of such invasive species within threshold limits. The world's first documented classical biological control of an invasive plant was from India. *Opuntia monacantha* (Cactaceae) was recognized as a weed occurring from Punjab to Assam and was serendipitously managed with the introduction of *Dactylopius ceylonicus* (Hemiptera: Dactylopiidae) in 1795 (ref. 15).

YRR pioneeringly recognized plant invasives in India[16]. His work on *Lantana camara* (the lantana, Verbenaceae) was trailblazing on the biological management of weedy invasives. Unfortunately, it is being ignored by biologists in India and elsewhere while discussing the biological management of this plant. *L. camara* as a weed has a long history and impacts severely in the agro-ecological environment of India. In the early 1900s, *L. camara*, a neotropical plant introduced into the Royal Botanical Garden in Calcutta (now known as the Acharya Jagadish Chandra Bose Botanic Garden, Kolkata) during the superintendence of William Roxburgh in 1807, turned into an aggressive invasive plant throughout India. In 1920, YRR summarized the activities in the early 1900s on the biological management of *L. camara* in Hawaii, USA, and the possible adoption of the same management strategy in India[17]. In 1893, the 'lantana bug' or 'Kew bug' *Insignorthezia* (*Orthezia*) *insignis* (Hemiptera: Ortheziidae), a polyphagous insect, was accidentally introduced into the Royal Botanic Gardens, Peradeniya, Ceylon (presently Sri Lanka) from the Kew Royal Botanic Garden, Kew, London. In 1915, it was accidentally introduced to Barwood Estate (today Barwood Tea Estate) in the Ouchterlony Valley, Gudalur, Nilgiris, Tamil Nadu, from Ceylon[17]. *I. insignis* is a pest in citrus, coffee, pepper, tomato and tea plantations[18]. Specimens of *I. insignis* collected from *L. camara* populations at Barwood Estate were sent to Leslie Charles Coleman, the Director of Agriculture, Mysore State, for determination. Coleman and his senior assistant Kunnathedeth Kunhikannan attempted the eradication of *L. camara* populations by slashing and burning, but in vain[17].

In the meantime, in Hawaii, *L. camara* populations grew to invasive proportions and the ranchmen pressurized the Hawaiian Department of Agriculture to launch measures to bring the populations under control. Before any official action could be taken, the ranchmen introduced *I. insignis* into Maui Island in 1899 and then into Oahu Island in 1904 (ref. 19), which was condemned by the economic entomologist Albert Koebele of Hawaii[17]. In 1902, the Hawaiian Department of Agriculture obtained eight species of insects considered specific to *L. camara* populations in Mexico and released them in Hawaii. Of these, *Lantanophaga* (*Platyptilia*) *pusilidactyla* (Lepidoptera: Pterophoridae) and *Ophiomyia lantanae* (Diptera: Agromyzidae) were determined as effective. Meanwhile, David Fullaway, entomologist with the Hawaii Board of Agriculture and Forestry was in contact with Fletcher and visited India to collect parasitoids of *Bactrocera* (*Dacus*) *cucurbitae* (Diptera: Tephritidae) in 1915. He conducted surveys in India and shipped *Opius fletcheri* (Hymenoptera: Braconidae) to manage insects on the Hawaiian populations of *B. cucurbitae* in 1916.

Unauthorized introduction of the polyphagous *I. insignis* into India and Hawaii, and the subsequent introduction of natural enemies of *L. camara* into Hawaii from Mexico and contacts with David Fullaway stimulated Fletcher to launch a survey of insects associated with *L. camara* in India before delving into classical biological control. The then Government of India surveyed for locally available potential natural enemies for *L. camara* before considering the introduction of any exotic natural enemy, a procedure accepted in recent times, and resorting to classical biological control. Fletcher arranged YRR's deputation from the Madras Department of Agriculture to the Imperial Agricultural Research Institute from 15 November 1916 to 31 March 1919, as an entomologist to survey natural enemies of *L. camara* throughout India. In the surveys conducted in India and Burma (presently Myanmar), YRR reported 148 insects, two pathogenic fungi and one parasitic plant associated with *L. camara.* Of these, *Asphondylia lantanae* (Diptera: Cecidomyiidae) and *L. pusilidactyla* were fortuitously introduced to India[17]. He concluded that the insects and diseases of *L. camara* found in the survey were incapable of controlling this plant and recommended the introduction of additional exotic agents proven effective elsewhere, especially in Hawaii. Meanwhile, Coleman and Kunhikannan in Mysore had decided to initiate biological control of this weed (possibly interacting with Fullaway, who was visiting India then and Fletcher, but we have no documents in support of this), and contacted the Hawaii Department of Agriculture for the supply of *O. lantanae*. In 1920 and 1921, Kunhikannan travelled to Hawaii and arranged for five shipments of *O. lantanae* to India[20]. The flies in four of these shipments arrived dead. In one shipment, 273 live adults were recovered and released in and around Bangalore (now Bengaluru). Progenies of none of these flies could be recovered in and around the city for several years later; however, in 1933, the fly was unexpectedly found on the berries of *L. camara* in Bangalore. Further surveys proved that the fly was well-established all over India and Burma[21].

The survey conducted by YRR on possible local natural enemies of *L. camara* was the crucial groundwork, urgently required to launch a classical biological control strategy. This groundwork laid about a century ago led to the introduction of additional natural enemies of *L. camara*, such as *Teleonemia scrupulosa* (Hemiptera: Tingidae) in 1941 by the Forest Research Institute (FRI), Dehra Dun; *Uroplata girardi* (Coleoptera: Chrysomelidae), *Salbia haemorrhoidalis* (Lepidoptera: Pyralidae) and *Diastema tigris* (Lepidoptera: Noctuidae) by the Commonwealth Institute of Biological Control reporting to the Commonwealth Institute of Entomology [London; now Centre for Agriculture and Bioscience International (CABI)] for the Central Plant Protection Training Institute, Hyderabad in 1969 and 1970, and *Octotoma scabripennis* (Coleoptera: Chrysomelidae) and *U. girardi* in 1971 by FRI[22].

YRR also described *Chromolaena odorata* (=*Eupatorium odoratum*; Asteraceae) introduced as an ornamental plant into the Royal Botanical Garden in Calcutta in 1837 that escaped and spread widely in Northeast India and Burma[17]. YRR recommended several precautionary steps to restrict the spread of *C. odorata* into new regions. However, *C. odorata* reached Kerala after World War II through the contaminated clothing of returning soldiers from the Northeast. In the Booker Prize-winning novel *The God of Small Things* (published in 1997), which is set in the Kerala of 1969, Arundhati Roy[23] mentioned efforts of an entomologist in controlling *C. odorata* which she called 'Communist Pacha', a common name used for this weed in Kerala (p. 7). Classical biological control of *C. odorata* was taken up by introducing *Pareuchaetes pseudoinsulata* (Lepidoptera: Arctiidae) in the 1970s, and *Cecidochares connexa* (Diptera: Tephritidae) in 2005 (ref. 24).

In the 1920s, when our understanding of invasive weeds was meagre, YRR not only identified the existence of invasive weeds, but also raised concerns in various publications. His 1920 report includes a description of other weeds, including *O. monacantha*, sensitive plant *Mimosa pudica* (Fabaceae), *Lippia geminata* (Verbaneceae), *Pontederia crassipes* (=*Eichhornia crassipes* (Pontederiaceae)), *C. odorata*, *Jatropha gossypifolia* (Euphorbiaceae), *Ulex europaeus* (Fabaceae) and *Cytisus scoparius* (Fabaceae)[17]. His pioneering work on recognizing invasive species and their vulnerability for classical biological control has laid a solid foundation for this aspect of research in India[17].

Desert locust

YRR's formal journey with *S. gregaria* started in 1930 when he started working at Quetta, Baluchistan, and later when he was stationed at Karachi as the Locust Entomologist until 1939. His extensive work on the bionomics of *S. gregaria* was officially submitted in 1941 and the monograph was press-ready in 1945, but was published only in 1960 (ref. 11). Meanwhile, YRR and other scientists, including M. A. Husain, K. R. Karandikar, S. D. Misra and M. L. Roonwal published systematic locust research separately as well. YRR through this work brought all the then available understanding of desert locusts together and it stands as a useful publication even today[2–9,25]. This compiled work that has resulted from a decade-long intensive work by YRR and his research team at the Locust Research Institute includes a wealth of data and elaborate notes on the bionomics, population density, outbreaks, lifecycles in different years, breeding conditions, distribution and details pertaining to other locust species such as *Patanga succincta* and *Locusta migratoria* (Orthoptera: Acrididae). Bulk of the work reported was carried out in Quetta, Karachi, Pasni (Balochistan coast), and at several smaller stations in Balochistan, Sind, Rajasthan and northwestern India. This monograph is divided into two parts, the first dealing with the solitary phase, and the second with the past locust invasions in India. The first part includes an account of the origin of *S. gregaria* studies in India and physiographical, climatic, vegetational and faunal characteristics of the studied region, survey methods employed for the study, details of the distribution and activities of *S. gregaria* during 1931–1938 and the bionomics. The second part includes details of various locust invasions in India between 1861 and 1939, correlating them with climate and weather data[2,3,7–9,23].

YRR's other contributions

YRR played a key role in the establishment of the Entomological Society of India in 1938, where he was the chief editor of the *Indian Journal of Entomology* from 1949 to 1957 (refs 11, 12). He served as an associate editor for the *Bulletin of Entomology* until 1966 (ref. 12). He was a Fellow of the Indian Academy of Sciences, Bengaluru, an Honorary Member of l'Association Internationale d'Acridologie, Paris, France, and a member of the FAO panel of experts to develop a long-term policy on desert locust control. In recognition of his valuable services to agriculture, the Government of India conferred the Dewan Bahadur and Rao Bahadur titles. YRR was elected president of the section of Entomology and Agricultural Sciences at the Indian Science Congress held in Benaras in 1941 and Calcutta in 1943. Also, he was elected president of the Entomology section at the first All India Congress of Zoology held in Jabalpur in 1959 (ref. 11). Between 1920 and 1960, he published several papers on diverse subjects, including agriculturally important pestiferous insects[26–28]. He has worked on various aspects of agricultural insect pests of India and Mesopotamia (at present, most of Iraq, Kuwait, the eastern parts of Syria, southeastern Turkey and regions along the Turkish–Syrian and Iran–Iraq borders)[13,29]. Working on a range of aspects of entomology was common in those days. In alignment with that style of working, YRR also studied various groups of arthropods and different disciplines of Arthropoda. He worked on the Lepidoptera, Hemiptera, Diptera, Hymenoptera, Coleoptera, gall-inducing insects, Crustacea, and entomopathogenic viruses and transmission of plant diseases[30–52].

Conclusion

This note is an attempt to remember YRR and his contributions to Indian entomology. We wish to reiterate his research generated interest in the field of biological control and desert locust in India in the early decades of the 20th century. YRR's vision and efforts to explore and manage *L. camara* through biological control agents were novel, bold and trailblazing. A formal record of desert locust was made in 1803 from the Indian subcontinent[53] and the establishment of the Locust Warning Organization in Karachi (undivided India) in 1939. Indeed we have come a long way in predicting the locust outbreak; however, a sustainable early warning system is still evasive. A recent outbreak of this pest in several countries of Africa (Ethiopia, Eritrea, Somalia, Kenya, East Africa), the Middle East (Saudi Arabia, Egypt, Oman, Yemen, Iran), South Asia (India and Pakistan), has left us pondering about our understating of this pest[54]. In East Africa and Yemen alone, it is predicted to cause losses of about 9 billion US dollars[55]. A lot more is yet to be researched on the management of this pest and specially in India, not much research has happened lately. Looking back, YRR's work on *S. gregaria* is monumental, stunning and unique.

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