

Following the tales: The Jonah's *Ricinus* biblical worms, *Olepa schleini* in Israel a local relict or an invasive alien species

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Abstract

The members of the moth genus *Olepa* were described from the South and South Asian countries (Indomalayan realm). In 2005, a new species of moth *O. schleini* Wit, Müller, Kravchenko, Miller, Hausmann & Speidel, 2005 was described from Israel extending the geographical range of the genus to the Palearctic realm considering the species as a Paleo-Tropical relict. In 2006, this moth species was assumed to be Jonah's worm mentioned in Jonah's book 2500 years ago with the proposal of 'Critically Endangered' status. In 2012, the above status and rediscovery of 'Jonah's worm' were put for debate, as the host plant castor is not native to Israel. In early 2020, the same species and its subspecies were reported from peninsular India with genetic data indicating the possible introduction of the species from India to Israel. The recent three new species descriptions of *Olepa* moth with phylogenetic data from peninsular India supports the studies of 2012 and ascertains the possible introduction of the species from India to Israel. Discussions are made on the agricultural history of Israel and the reason for such disjunct distribution of the species *O. schleini* from Israel and India.

Keywords: *Olepa schleini*, Israel, India, castor, biogeography, invasive alien species.

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Introduction

The species of the genus *Olepa* Watson, 1980 are reported from South and South-East Asia (Walker, 2007). In 2005, *Olepa schleini* was described from the Mediterranean coastal plain of Israel by Witt *et al.* (2005). As per Muller *et al.* (2006), adult of *O. schleini* was first collected from Nahal Shiqma (southern coastal plain of Israel) during August, 1999 and the distribution was restricted to a very small area of six rivers (= Nahal) in the central and southern coastal plain of Israel (Tananim, Alexander, Ayalon and its tributary Yarqon, Shiqma and Gerar a tributary of Besor). The larvae were first collected on the Castor species *Ricinus communis* Linnaeus, 1753 (Euphorbiaceae) from Gerar in 2001 (Muller *et al.*, 2006). Muller *et al.* (2006), declared it as an endemic to the coastal plain of Israel and a Paleo-Tropical relict. They went on to declare it as 'Critically Endangered' by applying the IUCN criterion with limited sampling in Israel. As rightly questioned by Rittner *et al.* (2012) about its origin in Indian subcontinent, the present

paper aims to put forward the logic and scientific studies occurred here in India.

Reference of *O. schleini* as Biblical worm of Jonah's book

Interpretation studies by Hausmann & Müller (2006) on the tiger moth species of *O. schleini* from Israel claimed it as 'Biblical worms' from the biblical book on Jonah, and assumed it as rediscovery of the Jonah's worm mentioned in the book 2500 year ago. As per the mythological story, Jonah was a prophet not believing in the divine mercy. God wanted to teach Jonah, a lesson during 787-747 BC in Nineveh of today's Iraq. Jonah learned obedience when God gave him an object a "kikayon" and a "worm". The perfect translation for Kikayon is not available as some authors hypothesizes it as a Castor plant (Mandelkern, 1937; Simon, 1994); some says it as *Lagenaria siceraria* (Cucurbitaceae) (Amar, 2012), and in English it is translated as 'gourd', and sometimes 'vine' (Hausmann & Müller, 2006).

The origin of Castor plant (*Ricinus communis* Linnaeus, 1753)

Castor plant belongs to the Euphorbiaceae family and has four centers of origin namely, (i) Ethiopian-East African region, (ii) Northwest and Southwest Asia and Arabian Peninsula, (iii) Subcontinents of India and (iv) China (Anjani, 2012). Further, she added that Ethiopian-East African region is the most appropriate site of origin due to high diversity in Ethiopia (Moshkin, 1986; Carter and Smith, 1987; Anjani, 2012). As per Watt (1892), it is native to India based on the references of medicinal uses of the plant in Sanskrit literature and evidences at the foothills of Himalayas. ICAR-IIOR (2020), suggested four centres of origin: West Asia, South West Asia, India and China.

In 2013, Israel government published a list of "Israel's Least Wanted Alien Ornamental Plant Species" and castor was in that list as Invasive (Invasion stage) (Dror, 2013) plant. Castor entered Israel through Africa in ancient times (Rittner *et al.*, 2012). India shares largest area (11.48 lakh ha.) and highest productivity (1666 kg/ha) of castor in the world (Anonymous, 2020). India, Brazil, USSR, China and Thailand are the major castor producing countries and the major importing countries are the USA, the USSR, the EEC and Japan (Sujatha *et al.*, 2011).

Muller *et al.* (2006) reported the larvae of *O. schleini* feeding on castor plant and is the first known host plant. Witt *et al.* (2005) termed it as monophagous pest on castor. Further, Rittner *et al.* (2012) added nine new host plants (*Cussonia paniculata*; *Ipomoea batatas*; *Brassica oleracea*; *Epipremnum pinnatum*; *Strobilanthes anisophyllus*; *Barleria obtuse*; *Nicotiana glauca*; *Passiflora edulis*) and stated all these host plants are not native to Israel.

Record of the species *O. schleini* from Peninsular India

During our collection survey from the peninsular India, some of the collected specimens were exactly matching the morphological descriptions and male genital characters of *O. schleini* from Israel. As the Oriental and Palearctic regions shared different zoogeographies, the specimens were put for DNA barcode studies. From the DNA barcode studies, the specimens were confirmed to be *O. schleini* from India, making it a new

record for the country (Kalawate *et al.*, 2020a). In the same study, a subspecies i.e., *O. schleini chandrai* Kalawate, 2020 was described based on morphological, genitalia and barcode studies. It has contrasting morphological difference with *O. schleini* from Israel and shallow genetic diversity on the mt COI DNA.

Materials and Methods

The present study was taken up to prove the logic behind the origin of the *O. schleini*. The map of the extant species recorded from the South and South-East Asia is prepared using open free QGIS software. The phylogenetic tree was adopted and modified from Kalawate (2020b). To understand better the occurrence of the species from the genus and their distribution a checklist has been prepared and presented in Table 1 with their host plant. In the forgoing pages we will see the concurrence of the Palearctic species in the peninsular India.

Results and Discussion

From the map and the table 1 it is clear that the origin of the species of the genus *Olepa* are from the South and South East Asian countries with the only exception of *O. schleini*.

Biogeography, taxonomic studies and inferences on the range of distribution

In Israel, *O. schleini* was collected under a long-term project started in 1986 to study insect fauna (focusing mainly on Lepidoptera) in a collaborative effort with the Nature and Parks Authority of Israel, the Tel Aviv University, the Hebrew University Jerusalem, and the Museum Witt, Munich, Germany (Muller *et al.*, 2005). Israel is an agriculturally developed country and supposed to be a world-leader in agricultural technologies including drip irrigation and squeezing water drops from air (Anonymous, 2021a). Israel and Indian agricultural scientist are sharing lot of technical knowledge. India has made Israel as a strategic partner in the field of Agriculture under the Indo-Israel Agricultural Project (IIAP) (Anonymous, 2021b). This technical know-how is being shared by Israel to other countries and there are chances that during these technology transfers and sharing of biological resources the members of the species *O. schleini* might have introduced to Israel unknowingly. This has been clearly established in the studies of

Kalawate *et al.* (2020a), where different population of *O. schleini* in India and Israel having same morphological features and genetic homogeneity (mt COI gene) were studied. Supporting the above statements Kalawate *et al.* (2020b) have described three new species and a sub species from peninsular India. The phylogenetic tree based on the mt COI gene fragment (599bp) suggests *O. toulgoeti* reported from Nilgiri hills of the Western Ghats as a sister species to *O. schleini* described from Israel. From Fig.1 and Table 1 it is clear that the centre of origin of this group is South and South-East Asia mainly from India, Sri-Lanka and Thailand.

As per the earlier reports, if *O. schleini* is endemic and paleo-tropical relic of Israel, then the host plant should also be a local species. Nevertheless, in this case, castor is not native to Israel and the biblical event in Jonah's book was believed to have taken place some 2500 years ago. Agricultural developmental activities in Israel are recent compared to biblical event of Jonah's book. In such an agriculturally developed country, how this moth was undiscovered these many years is a brilliant argument put forth by Rittner *et al.* (2012). Hausmann & Müller (2006) stated that only one lepidoptera i.e. *Dysgonia algira* (Linnaeus, 1767) was recorded as a pest of castor in the literature until the recent discovery of *O. schleini*, a leaf eater in Israel.

On the contrary, *Dialeurodes citri* (Ashmead, 1885) (Hausmann & Müller, 2006), *Phycita diaphana* Staudinger, 1870, *Stomphastis conflua* (Meyrick, 1914), *Spodoptera exigua* (Hübner, 1808), *Dysgonia algira* (Linnaeus, 1767) were the pest reported by Rittner *et al.* (2012) in Israel for castor other than lepidopteran pest.

In India, the major pests reported on castor are: *Amsacta albistriga* (Walker, 1865), *Achaea janata* (Linnaeus, 1758); *Spodoptera litura* (Fabricius, 1775); *Conogethes (Dichocrosis) punctiferalis* (Guenée, 1854); *Empoasca flavescens* (Fabricius, 1794); *Retithrips syriacus* (Mayet, 1890); *Trialeurodes ricini* (Misra, 1924); *Liriomyza trifolii* (Burgess, 1880); *Spilosoma obliqua* (Walker, 1855) and *O. ricini* (Lepidoptera: Erebidae) (ICAR-NBAIR, 2019).

The reported pests are either foliage feeder or sap-sucker and not stem-borer (eater) as mentioned in the Jonah's book. The worm mentioned in the biblical book seems like stem

borer as it was gnawing the stem and withering of the plant occurred in a night. *O. schleini* is a leaf-eater (Rittner *et al.*, 2012). Hence, as rightly stated by Rittner *et al.* (2012), the biblical worm is not *O. schleini*.

Out of the eleven reported species of *Olepa* from the world, nine species are from India and one each from Sri Lanka and Thailand (Fig. 1) (Kalawate *et al.*, 2020b). Recently, Kalawate *et al.* (2020a, b) described three new species namely *O. ghatmatha* Kalawate, 2020; *O. suryamal* Kalawate, 2020; *O. zedesi* Kalawate, 2020 and two subspecies, *O. suryamal rekhae* Kalawate, 2020 & *O. schleini chandrai* Kalawate, 2020 including a new country record for *O. schleini*. With these additions, now the species in the genus *Olepa* stands at 14 from the world including 12 species and 2 subspecies from India.

The type locality of *O. schleini* from Israel and the place where it is reported in India are separated by a minimum aerial distance of 4,000km. There seems to be disjunctive distribution range for the species from India and Israel without having their distribution in between countries. To date no other species of *Olepa* are recorded out of India, Sri Lanka, Nepal, Northern Pakistan and Thailand except *O. schleini* (from Israel). Based on our earlier mt DNA barcode studies on *O. schleini* (from Nandurabr, India) (Kalawate *et al.*, 2020a) and reports of new species based on mt DNA barcode studies from peninsular India (Kalawate *et al.*, 2020b) we are of the opinion that origin and centre of diversity of this Tiger moth could be South or South east Asia.

Conclusion

Based on our mt DNA barcode studies and field sampling of the *Olepa* moths in India we defer the Muller *et al.* (2006) consideration of *O. schleini* endemic to the coastal plain of Israel and we warrant further molecular studies to consider the species as Paleo-Tropical relic (Witt *et al.*, 2005).

We support the arguments of Rittner *et al.* (2012) regarding the feeding behavior of *O. schleini* and the the origin of castor plant which is a host plant for *O. schleini* in Israel. We consider it premature to consider *O. schleini* as 'Critically Endangered' (Muller *et al.*, 2006) without studying the distribution range of the species. The 'Biblical worms' mentioned in the Jonah's book could be a stem

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borer as mentioned by Rittner *et al.* (2012) and *O. schleini* could be very recently introduced

to Israel from India through the host plants during the Israel's new agricultural reforms.

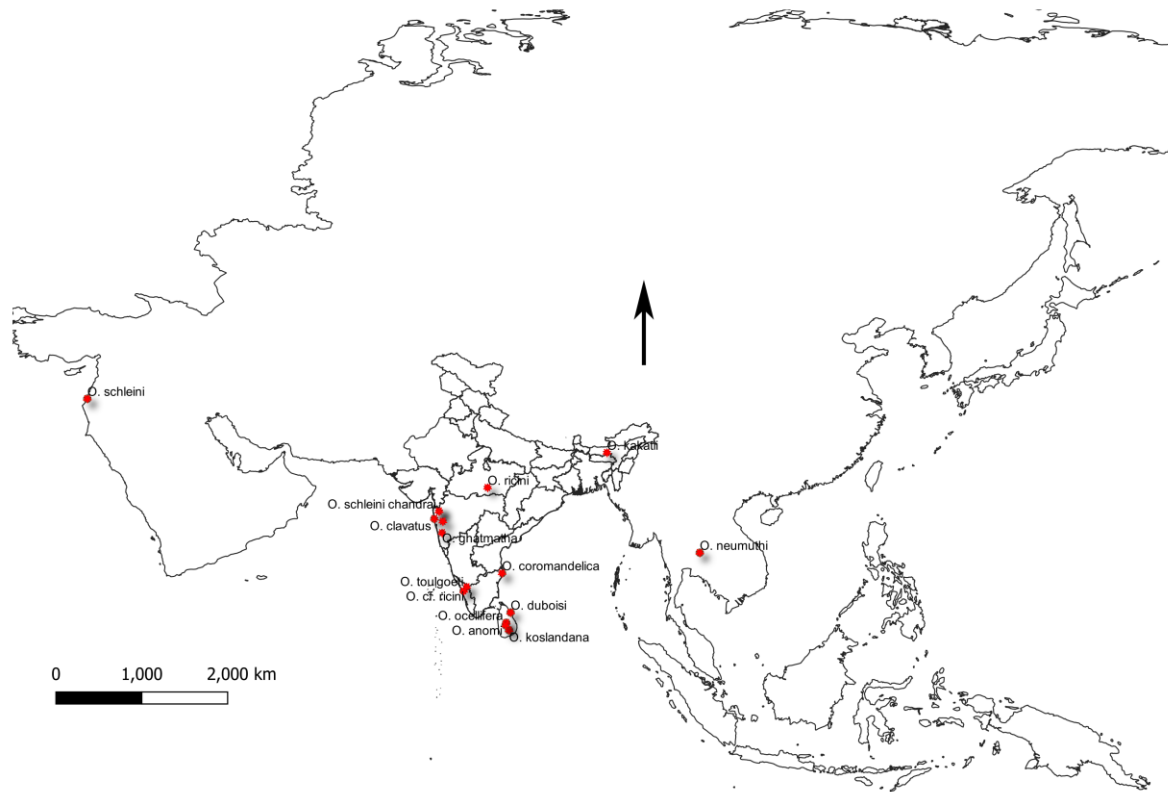


Figure 1. Map showing the type localities for the extant species of *Olepa* from South, South East Asia and Israel.

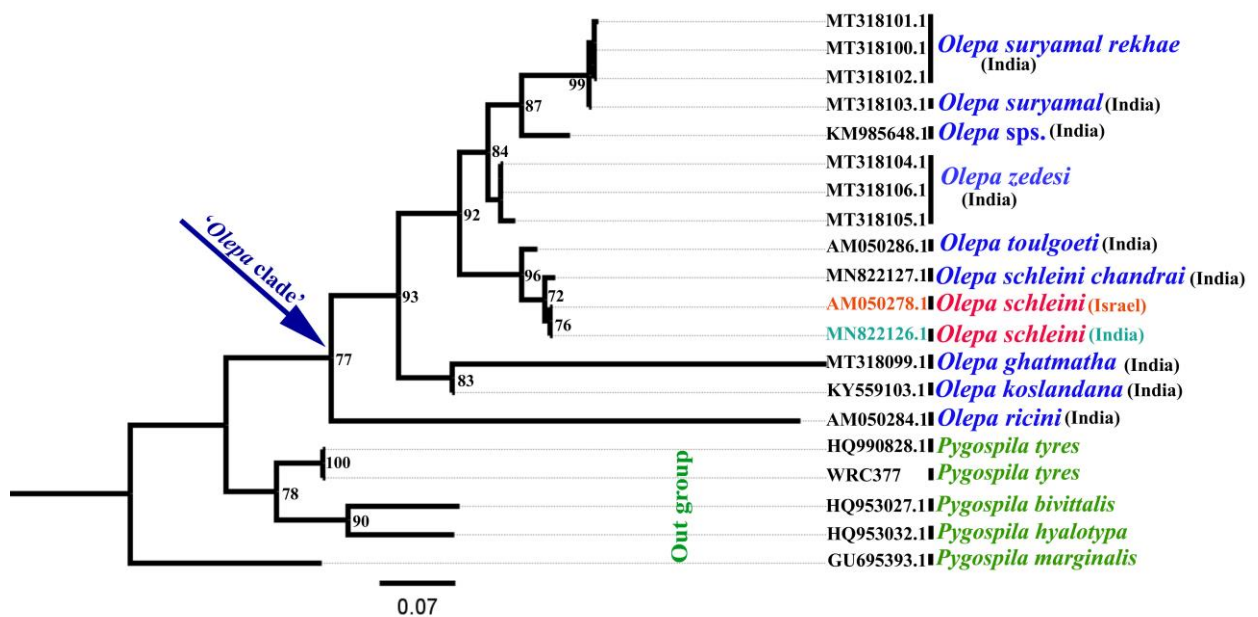


Figure 2. mt COI DNA based (599 bp) Maximum Likelihood (ML) tree for the species of *Olepa* moths (details as in Kalawate *et al.*, 2020b).

Table 1. The known host plant species of *Olepa* species with their distribution ranges

Sl. No.	Species	Known distribution ranges (Kalawate, 2020b)	Known host plant details
1	<i>O. ocellifera</i> (Walker, 1980)	Bangladesh, India (Indian Himalaya, Assam), Sri Lanka	<i>Notonia</i> (Asteraceae); <i>Fagraea</i> (Loganiaceae); <i>Dahlia</i> (Asteraceae) (Moore 1883)
2.	<i>O. duboisi</i> Orhant, 1986	India (Kerala), Sri Lanka	Pissenlit (Dandelion); Plantago (Plantain) (Plantaginaceae); <i>Cichorium</i> (endives) (Asteraceae) (Orhant, 1986)
3	<i>O. anomi</i> Orhant, 1986	Sri Lanka	Not known
4	<i>O. kakatii</i> Orhant, 2000	India (Assam)	Not known
5	<i>O. ricini</i> (Fabricius, 1775)	Bangladesh, Nepal, Northern Pakistan, Sri Lanka, Thailand throughout India,	Cotton (Malvaceae); castor (Euphorbiaceae) (Fabricius, 1775); sunflower (Asteraceae); sesame (Pedaliaceae); maize (Poaceae); ivy gourd (Cucurbitaceae); brinjal (Solanaceae); sweet potato (Convolvulaceae); banana (Musaceae) (ICAR-NBAIR 2019); polyphagous (Gaur and Kumar, 2019).
6	<i>O. schleini</i> Witt <i>et al.</i> , 2005	India (Maharashtra), Israel	Castor (Euphorbiaceae) (Witt <i>et al.</i> , 2005)
7	<i>O. neumuthi</i> Orhant, 2012	Thailand	Castor (Euphorbiaceae) (Orhant, 2012)
8	<i>O. clavatus</i> (Swinhoe, 1885)	India (South India, Maharashtra)	Not known
9	<i>O. toulgoeti</i> Orhant, 1986	Orissa, South India	Not known
10	<i>O. koslandana</i> Orhant, 1986	India (Karnataka, Coromandel, Orissa, Bihar, Jharkhand), Sri Lanka (koslanda)	Not known
11	<i>O. coromandelica</i> Dubatolov, 2011	India (Coromandel)	Not known
12	<i>O. ghatmatha</i> Kalawate, 2020	India (Maharashtra)	Not known
13	<i>O. suryamal</i> Kalawate, 2020	India (Maharashtra)	Not known
14	<i>O. zedesi</i> Kalawate, 2020	India (Maharashtra)	Not known
15	<i>O. schleini chandrai</i> Kalawate, 2020	India (Maharashtra)	Not known
16	<i>O. suryamal rekhae</i> Kalawate, 2020	India (Maharashtra)	Not known

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