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Citrus Butterfly (*Papilio demoleus* Linnaeus) Bioiogy and Management: A Review.

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Review Article

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ABSTRACT

The lemon butterfly is one of the economically important pests whose larval forms cause serious damage by devouring large quantity of foliage of Rutaceae family with Special preference towards both wild and cultivated species of citrus during the later stages of their development. The genus *Papilio* is widely distributed all over the world. Different species of citrus butterfly occurs in different parts of the world. However, *Papilio demoleus* Linnaeus (PDL) is the most prevalent species and was found in greater parts of Asia, Farmosa and Japan etc. The biology and developmental periods are mainly dependant on the climate, location and plant species on which it is feeding. The larval population density will be high during October to December months and July to December is the most favourable period of its activity in general. PDL was able to survive during the winter even though temperatures dropped below 0°C. The total life period varied between 21-50 days and with 3-9 generations per year depending on the weather at various locations. For managing this pest the different biological agents include the yellow wasp (*Polistes hebreus* F.), preying mantis (*Creobrator gemmatus*) and spiders etc. The pupae were parasitised by *Pteromalus puparum* and eggs by *Trichogramma, Telenomus* species. *Distatrix (=Apanteles) papailionis* (Vireck) is a potential braconid larval parasitiod causing up to 73% egg and larval parasitism, the egg and PDL and *P. polytes* species in India. The biocompatible, biodegradable bio-pesticides like BTB, BTK, NSKE, azadirachtin, diofenolan, methonine etc., which interfere with the pests morphological and physiological aspects like feeding, moulting, cellular construction and cell immune system without affecting the natural environmental balance were clearly reviewed in this paper.

INTRODUCTION

The genus Citrus is unique in its diversity of forms and no other fruit crop can parallel it. Citrus crop posses great adaptability to various climatic conditions and hence grown equally both in tropical and subtropical regions as well as some favourable parts of the temperate regions of the world. Citrus industry is the third largest, in the world after mango and banana. In India citrus crop occupies a prominent place covering an area of about 8.5 L ha with an annual production of 74.64 L tonnes with a productivity of 8.8 t/ha (NHB, 2011). Andhra Pradesh (AP) is one of the major citrus producing states in India and ranks first in Sweet orange (*C. sinenesis*) and acid lime (*C. aurentifolia*) area and production.

Citrus crop is being infested by around 165 species of economically important insect pests in India causing up to 30 per cent yield loss (Pruthi and Mani, 1945). Similarly, 250 and 120 insect species were also reported from India [1]. However in America 823 species of different insect and mite pests were reported. About 55, insect and mite species were reported from Rayalaseema region [2] and a dozen of them attack this crop regularly right from nursery stage to the harvest with cognizable damage. Four species of citrus butterflies viz., P. demoleus L., P. polytes L., P. polymnestor and P. helenus were recorded to be damaging citrus in south India [3]. The lemon

butterfly, *Papilio demoleus* Linnaeus (PDL) is one of the economically important pests whose larval forms cause serious damage to citrus family by devouring large quantity of foliage during the later stages of their development [4]. Lemon butterfly is a serious pest of citrus in India. The caterpillars are voracious feeders of young seedlings and cause death of the seedling within no time [5]. Its principal host plants are the members of the genus *Citrus* [6]. Thakare and Borle [7] stated that the larvae of *P. demoleus* also damage bael (*Aegle marmelos*), kadhu limb (*Murraya koenigi*), bawachi (*Psoralea corylifoli*) and bhira (*Chloroxylon sweiteni*) and caused 100 per cent defoliation in Maharashtra. Secondary hosts include various genera of Rutaceae, such as *Murraya, Triphasia Glycosmis, Aegle, Zanthoxylum, Toddalia, Euodia, Atalantia* and *Poncirus* in the forests of Malaysia [8]. In India it is mostly found in the plains but can be found on the hills of peninsular India and up to 7000 feet in the Himalayas. Several insecticides offer quick and effective control of the pest. Keeping in view their adverse effects on the environment and other non-targeted organisms here an attempt is made to review the histotical distribution, biology and biological management methods which are best suited to integrated pest management programme.

Historical Background and Distribution

Papilio demoleus Linnaeus, the Lime Swallowtail, is one of the most wide spread members of the family Papilionidae and one of the most studied butterfly species partly due to the quick expansion of its range and potential danger to agriculture. It was reported to be a pest of citrus throughout India but not in U.S.A [9]. First record of PDL population in the Americas is by Guerrero et al. [6] in Santo Domingo. Apart from its first appearance in the Caribbean region, most of the range expansion of PDL appears to be due to immigration and subsequent assimilation at new territories, following corridors of *Citrus* plantations everywhere. It is commonly known as the lime swallowtail, citrus swallowtail or chequered swallowtail and is found throughout Southern Asia. It was widely distributed from Farmosa to Arabia including Burma, Bangladesh, Ceylon, India and Pakistan [10].

Lime swallowtails are thought to have originated in Madagascar are native to Asia ranging Iran in the west across India and southern Chinato Japan and Australia in the east. This species is extremely successful in the Asia greatly expanding its range within historic times. These are described as the most destructive pests in the citrus nurseries [11]. In 2003 and 2004, PDL appeared in central Syria, near Al Qaryatayn and Palmyra, and shortly afterwards, in 2005, it was recorded for the first time in Turkey [12]. Recently it was recorded in Domonican Republic, Puerto Rico and Jamaica [13].

Papilio demoleus is a common and wide spread swallowtail butterfly. It gets its common names from its host plants, which are usually Citrus species such as the cultivated lime. Unlike most Swallowtail butterflies, it does not have a prominent tail. The genus is widely distributed all over the world. However, PDL was found in greater parts of Asia, Farmosa and Japan. The butterfly is a pest and invasive species from the Old World which has spread to the Caribbean and Central America. The PDL is native to the old world where six sub species are recognized.

They are

- *P. d. demoleus* Linnaeus, 1758 - Across Asia from China to the Arabian Peninsula.
- *P. d. libanius* Fruhstorfer, 1908 - Taiwan, Philippines, Sula, Talaud.
- *P. d. malayanus* Wallace, 1865 - Sumatra and the Malaysian peninsula.
- *P. d. novoguineensis* Rothschild, 1908 - Papua New Guinea.
- *P. d. sthenelus* Macleay, 1826 - Australia.
- *P. d. stenelinus* Rothschild, 1895 - Sumba, Flores and Alor.

In the PDL group of Swallowtail butterflies, three of the five recognized species are restricted to Madagascar, whereas the remaining two species range across the Afro-tropical zone and southern Asia plus Australia. All Asian subspecies feed on Citrus, which is commonly planted as a crop or ornament in towns and smaller settlements and probably facilitates range expansion of PDL in Asia [14]. Among these PDL is found throughout tropical and subtropical region of Southern Asia ranging from Saudi Arabia ,Iran and middle East to India, Nepal, Soutern China, Japan, Taiwan and South through Malaysia, Indonesia and New Guinea to Australia.

The butterfly has also been referred to as the *Butterfly of death*, a name it shares with a morphologically similar species, *Papilio demodocus* from Africa and Madagascar. Carcasson considered *P. demodocus* to be the ancestral species, from which the three species endemic in Madagascar were isolated. The species *malayanus* was accidentally introduced to the Caribbean [15].

Papilio polytes Linnaeus. (Lepidoptera: Papilionidae) is a tropical or subtropical papilionid butterfly distributed from Southeast Asia to the South western Island of Japan [8,16].

Papilio demodocus is a butterfly, common in southern Africa. It occurs throughout sub-Saharan Africa, extending into Saudi Arabia, Yemen, and Oman [14]. It is most abundant during the rains when its larvae (caterpillars) may cause damage to citrus trees.

Black Swallowtail, *Papilio polyxenes* Fabricius is distributed in most of the eastern U.S., North into Quebec, west into South Saskatchewan, Colorado and se. California; south to n. South America. Sub species *coloro* in desert south west.

The Jamaican orange dog, *Papilio andraemon* Hubner is a pest of citrus in Jamaica causing extensive damage to young citrus seedlings. It was first known to be reported from specimens caught in Cuba by Rothschild and Jordan [17]. Later it's presence in Jamaica was given by Lewis [18] along with its description.

P. schmeltzii is Fiji's largest butterfly and the only Papilionidae in Fiji. *P. Schmeltzii* was originally described by Gottlieb August Wilhelm Herrich-Schaeffer (a German entomologist) in 1869. Two endemic species of Swallowtail butterflies are found on the eastern edge of the Pacific Islands which are *Papilio godeffroyi* in Samoa (Savaii, Upolu and Tutuila) and *P. Schmeltzii.* The host plant of *P. schmeltzii* observed in natural habitat is *Micromelum minitum*. The preferences of the food plants by adult *P. schmeltzii* are variable due to their availability in that area but the adult butterflies favoured *Stachytarpheta urticifolia* and were also seen visiting *Lantana camara* and on *Ixora coccinea* flowers in some areas (Beqa Island). Although *P. schmeltzii* is common in Fiji Islands, they occur in low numbers in their natural habitat in Fiji [19].

Incidence and Economic importance

The New World arrival of this vagile lepidopteron pest is a potential threat to the citrus industries in the region. The larvae are a serious pest of citrus nursery stock (trees 1-2 ft. in height) and other young citrus trees and are capable of defoliating entire nursery groves. Larvae may utilize young foliage on more mature trees [4,20,21]. Most of the *Papilio* species reported till now preferably feed on various plants of Rutaceae family with Special preference towards both wild and cultivated species of Citrus. Among all the known species of *Papilio*, *P. demoleus* is the most prevalent and economically important one. Out breaks of PDL were not uncommon as experienced in Nagpur region [22]. Similarly, the pest occurred in epidemic form during eighties in Southern zone of Andhra Pradesh [23]. PDL may cause complete (100%) defoliation of infested young plants [7,24]. Similarly 83% defoliation of Sweet orange plants in AP was reported by Narayanamma et al [21]. From Rayalaseema region and >40% defoliation reported in acid lime gardens in Tamilnadu region during the October to January [25].

PDL incidence was noticed to be high during the rainy and winter periods. Pest activity was severe during October to December and first fortnight of January on sweet orange and during November to January in acid lime in Rayalaseema region in AP and high relative humidity, low temperatures favoured its larval activity [26]. PDL incidence was high in the month of August September in Bundelkhand of Uttar Pradesh [27], June to October in *C. limon* in India [28] and during November to February in acid lime and Kinnow Limes [21,28]. Similarly in Rajasthan PDL activity was reported during August to February months on Bael (*Eagle marmelos*) and their egg and larval development was positively correlated to relative humidity and negatively correlated to maximum temperature and rainfall [29]. Larval population is maximum (0.13 ± 0.02larvae/branch) during August and February months at temperatures ranging from 28-30^{o}c and relative humidity between 82-84% [29].

The larval population density of *P. polytes* was high during October to December months in citrus orchards of Malaysia Suwarno [30], Yadav et al. [31] reported February to June as peak activity period in Uttar Pradesh. In Nusaybin (Turkey), PDL was able to survive during the winter in 2005/2006, even though temperatures dropped below 0°C on two days in February (to -2°C). The peak larval activity of PDL was noticed during November to February on kagzi lime in Karnataka [32] and in January, February, June, July and October months in Madhya Pradesh [33]. The pest attacks mandarin and acid lime plantations almost throughout the year but is serious during July-August [34].

Bionomics of Citrus butterfly

Life cycle

The lemon butterfly, *Papilio demoleus* is a an economically important pest whose larval forms cause serious damage to citrus family by devouring the foliage heavily during the later stages of their development. The lime Swallowtail, PDL is sometimes called the chequered or citrus Swallowtail. It belongs to the family Papilionidae. It is a beautiful black yellow butterfly. The adult wingspan range from 80-100 mm. The hind wing has no tail. Its head and thorax are black with creamy yellow streaks on each side. The legs and abdomen were dusky black having creamy yellow colouration on the underside of the abdomen and the body was covered with black and yellow hairs. The upper portion of the forewing is largely black and the outer wing margin has a series of irregular yellow spots. Two yellow spots are present at the upper end of the discal cell with several scattered yellow spots in the

apical region. The upper hind wing has a red tornal spot and the discal black band is dusted with yellow scales. The underside is paler yellow with the black areas more heavily dusted with yellow antennae are black and club shaped. The male and female sexes are differentiated by observing the abdomen. In females the tip of the abdomen was flat and in males it is pointed. The adults fly in every month but are more abundant after monsoons. The female butterfly goes from plant to plant, laying a single egg at a time on top of a leaf which it holds onto with its legs, and flies off as soon as the egg is laid. The egg is round, light yellowish in colour, flattened at the base, smooth-surfaced and about 1.5 mm in height. Fertile eggs develop a small red mark at the apex. The active compounds identified as a flavanone glycoside, naringin (naringenin-7β-neohesperidoside), hesperidin (hesperetin-7β-rutinoside) in the epicarp of sour orange (*Citrus natsudaidai*) exhibited potent stimulatory kairomonal activity as did its leaves for egg-laying by the females elicited positive response at the concentration of 0.2% in a papilionid butterfly, *Papilio protenori* [35].

The newly hatched caterpillar stays in the middle of the upper side of the leaf. The first instar of the caterpillar is black, with a black heads and two rows of sub-dorsal fleshy spines. It initially feeds on small leaves attacking larger ones as it grows older.The second, third and fourth instars are dark, with glossy, dark-brown head, and white markings on the 8th and 9th segments of the caterpillar which resemble a white patch of uric acid deposited in a bird's droppings, helping them escape predation while remaining in moderately open places. From the fifth instar onwards, the caterpillars turn cylindrical in shape, tapered towards the rear, and uniformly pale green in colour with a white sub-spiracular band. The head is large and brown with a dull orange inverted V mark. The osmeterium is yellow at the base to orange at the tips. This fleshy, forked structure occurs just above the head on larvae of Swallowtail butterflies. It is normally hidden but can be everted out when the caterpillar feels threatened. It emits smelly compounds that deter some predators. An additional black band is developed on the 4th and 5th segments with two black and two bluish spots on them. During 4th and 5th instar feeding activities was rapid in comparison to 1st and 3rd instar stages [33].Typically, the butterfly undergoes five instars as a caterpillar and feeds for about 14 days in summer. The positive larval attraction is maximum for yellow colour and declines with the increase or decrease in the wavelength of maximum light transmission. Red and bluish-green colours repel the larvae[36].

The pupa, which is rugose, stout and 30 mm in length, has two projections to the front on its head and also one on its thorax and resembles that of the Common Mormon *Papilio polytes*, the difference being that the Common Mormon pupa has a deeper cut between the projections and its abdomen is more protruded on the sides, having a small point. They are attached to the thicker stems of the food plant, or to adjacent sticks and rocks. The pupa is dimorphic with regards to colour, with the colour developing according to the prevalent colour and texture in the background. The green morph, which is found amongst green vegetation and smoother textures, is light green and unmarked or with yellow dorsal markings. When situated among brown or dry objects, the pupa tends to turn light grey-brown to pink-brown and develop cryptic dark brown and black striation. Similarly, in *P. polytes* the pupal colour is green as against brown in PDL [37].

The duration of different life stages include egg period of 2.9 days, larval period 8.9 days, pre-pupal period 1day, pupal period 8.1 days and with a total life cycle period of 21 days on sweet orange, 31.6 days in acid lime in AP [26] and it is 21-41 days in Riyadh, 26-59 days with 8-9 generation per year in Pakistan and 49 days on citrus in Himalaya region [38]. The total developmental period from egg to adult was shortest on (21.03 days) on Sathgudi and longest (28.69) on curry leaf. It took 21.56 days on Rangpur lime and 22.66 days on Jambhiri [39]. Asokan [62] reported that the total life period of PDL as 30-50 days with an additional 6th instar on acid lime. The larval and pupal duration is longer on babchi (*Psoralea corylifolia*) than on lemon (*Citrus lemon*) and females prefer babchi for ovipostion compared to lemon[40].

The number of generations of PDL is dependent upon temperature, near the equator; nine generations have been recorded, while in warm temperate China, five generations have been recorded [18]. Resham et al. [5] reported five generations per year. In the ideal conditions of a laboratory, one generation has been recorded to take place in just over 30 days. In cold climates, the lime butterfly is known to pass the winter as pupae. Atluri et al. [28] reported 6 generations per year with a total life period of 46-52 days on *C. limo*n in India, Tiatula et al. [42] reported, 7 generations of PDL per year in Nagaland with total life period being longest (118 days) in 7th generation and shortest (33.5 days) in 3rd generation and population activity is maximum (40-73%) during June and Minimum (3.3%) in December months.

Host Range

Food plants of PDL in Asia are from family Rutaceae while in Australia and Papua New Guinea the butterfly also feeds on host-plants of family Fabaceae [18].

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Family Rutaceae

Cultivated lime, orange and lemons; *C. aurantifolia*, *C. grandis*, *C. limon*, *C. sinensis*, *Atalanta racemosa, Glycosmis pentaphylla*, *Glycosmis arborea, Ruta graveolens* Bael (*Aegle marmelos*), *Murraya koenigii*, *Chloroxylon swietenia*, Ber (*Ziziphus mauritiana*) *Acronychia pedunculata*, *Microcitrus australis* (Australian round-lime, Australian lime).

Family Fabaceae

Many species of Cullen : *Cullen australasicum*, *C. badocanum, C. balsamicum, C. cinereum, C. patens* (spreading scurf-pea, native verbine), *C. pustulatum* and *C. tenax* (tough scurf-pea, emu-foot, emu grass), and *C. leucanthum. Psoralea pinnata* (Fountain bush).

In India in all the areas the larvae are noticed on Rutaceous species only. The host preference of PDL lies in the order of sweet orange > curry leaf > acid lime [26]. Similarly, the hierarchy of oviposition preference of *P. polytes* on the host plants was *C. reticulata* ≥ *C. aurantifolia* > *C. hystrix* > *M. Koenigii* [30].

Management

In the management of lemon butterfly through various integrated pest management techniques can be adopted. Many pesticides were tested against this pest and found effective also [3]. Under present globalised situation of the world scenario, keeping in view the side effects of these pesticides on non targeted organisms including humans, environmental pollution, and chemical control is no more a valuable technique of pest management. Hence, pest management with bio-agents, botanicals and bio-rational pesticides are only reviewed here under.

Biochemical management

The terms “biorational pesticide” and “biopesticides”, referring to pesticides that have limited or no adverse effects on the environment, non-target organisms including humans. Biorational insecticides include: biochemical insecticides (botanicals, insect growth regulators, insect pheromones, photoinsecticides, and inorganics); biological insecticides, using of natural enemies such as parasitoids, predators, nematodes, and pathogens (virus, bacteria, fungi, or protozoa); and transgenic insecticides (genetically modified plants or organisms).

Natural enemies play an important role in limiting potential pest populations and they are more likely to survive in case of application of eco-friendly bio-pesticides. Bio-pesticides have broad modes of action on pests. This avoids resistance problems that exist with conventional pesticides. Bio-pesticides often work best in rotation with conventional products so that optimal pest management can be obtained while avoiding resistance problems

Biological insecticides

The young caterpillars of PDL were attacked by the yellow wasp (*Polistes hebreus* F.), preying mantis (Creobrator gemmatus) and spiders. The pupae were parasitised by *Pteromalus* sp. and eggs by another unknown hymenopteran parasite [9]. Ramzan and Darshan Singh [37] reported emergence of 124 pupae of *Pteromalus puparum* from a single PDL pupa. *Trichogramma Chilonis and Telenomus* sp. are egg parasitoids on lemon butterfly and as high as 75.9% egg parasitism was recorded on both PDL and *P. polytes* species [43]. Similarly, *Apanteles lunatus* and *Pteromalus puparum* are natural enemies of larvae and pupae on *Papilio demoleus* as observed in citrus orchards of Nepal [5]. The egg and larval parasitism by *Trichogramma, Telenomus* and *Apanteles* as high as 73% on PDL and *P. polytes* species [44]. *Distatrix (=Apanteles) papailionis* (Vireck) is a potential braconid larval parasitiod of citrus butterflies (*Papilio* spp.) causing up to 73% parasitism in India [45].

The parasitism of larval parasitoids on PDL is positively correlated with rain fall and relative humidity and negatively with temperature. Egg mortality of 87.4% due to *Ooenocyrtus* sp. on *P. homerus* population in Jamaica during July-October [46]. Some caterpillars of PDL are found parasitised by wasps, which lay dozens of eggs in them. The parasitic wasp larvae eat the caterpillar from the inside. Initially the vital organs are avoided, but by the time the caterpillar is ready to pupate even the vital organs are consumed. Soon after the caterpillar pupates, the parasitoids emerge from the pupa thus killing it. Different species of coccinellids, vespids and preying mantids were reported as predators on citrus butterfly [47]. Larval parasitisation by *Apanteles* (=*Ooencyrtus*) *papilionis*, *Apanteles* sp. and *Bracon hebetor* butterfly larvae was noticed on both sweet orange and acid lime during November to January in Rayalaseema region [26].

Three parasitoids are known to parasitize PDL larvae in India. They are *Apanteles* (=*Ooencyrtus*) *papilionis*, *Apanteles* sp. and *Bracon hebetor* (Hymenoptera: Braconidae). A braconid *Apanteles flavipes* and ichneumonid, *Melalophacharops* sp. are the predominant larval parasitoids and a chalcid *Pteromalus puparium* and an ichneumonid, *Holcojoppa coelopyga* are the major pupal parasitoids which could be utilized for effective control of the pest biologically. In Thailand, two kinds of egg parasites were found: *Ooencyrtus malayensis* Ferriere (Hymenoptera: Encyrtidae) and *Tetrastichus* sp. (Hymenoptera: Eulophidae). A larval parasite, *Erycia nymphalidophaga* Baronoff (Diptera: Tachinidae), was found. Additionally, *Brachymeria* sp. (Hymenoptera: Chalcididae) and *Pteromalus puparum* Linnaeus (Hymenoptera: Pteromalidae) are pupal parasites.

Other natural enemies of larvae found in Thailand were a predatory pentatomid bug, *Cantheconidea furcellata* (Wolff); reduviid bugs; birds; spiders; sphecids; and chameleons [18]. Spiders were the important mortality agents in the eggs and young larvae, meanwhile in the older larvae were *S. dichotomus* and *Podisus* sp., *Ooencyrtus papilioni* and *Pteromalus puparum* were the important parasitoids for the eggs and pupae of PDL, respectively [48].

Bio-rational insecticides

Resham et al., [5] first reported that *Bacillus thuringiensis* Berliner as highly effective bio-rational insecticide against *P. demoleus* larvae in Nepal. The same results were supported by Shivankar et al., [3] in India who stated that Dipel (*Bacillus thuringiensis* Berl.) spray at 0.05% gives good control of the pest. Entomopathogens like bacterium *Serratia marcesscens* and fungus *Fusarium* sp. also killed the pest population substantially. Some plant extracts like Pipal (Ficus religiosa), Beshram (*Manchoria hastaefolia*), *Parthenium histerophorus,* Neem (*Azadirachta indica)* and Datura (*Datura stramoneum*) significantly (52.8%) reduced PDL larval population [49]. Similarly the plant products allitin, replin, margosol and neem guard @ 1% aqueous extract gave >75% pest control in citrus. The leaf extracts of *Eucalyptus globulus* and *Ageratum conyzoides*, clove extracts of *Allium sativum* cause morphological abnormalities in PDL 5th instar larvae and thus are useful botanicals in the pest management [50]. BT applied @ 40BIU/ ha was found effective against 4th instar larvae of *P. glaucus* and *P. canadensis*. Its persistence against early instar larvae lasted up to 30days after spray [51].

Similarly, spraying with aqueous extract of neem seed kernal @ 0.5% twice at 8 days interval is effectively checks the pest population as it has strong antifeedant and repellant activity [52,53] who stated azadirachtin (0.3%) as effective one against citrus butterfly among the various neem products. The biopesticides *Bacillus thuringiensis* Var. Kurstaki (BTK), @ 2g/L and Azaditachtin 0.5% and Nimbecidin 0.03% at 4.5ml/L are effective botanicals against butterfly larvae [54,55,56,57]. A formulation of BT, Bactospeine, was found highly effective in controlling the pest [38]. BTK is non- toxic to *Distatrix (=Apanteles) papailionis* (Vireck), a potential braconid larval parasitiod of citrus butterflies [45]. Fawzi AL–Zubaidi, [58] recommended the use of BTK, a bio-control agent and as a powerful tool against lemon butterfly, especially, with the concentrations of 1.0 and 2.0 mg/ml. BT at 0.05% and 0.1% are effective against citrus butterfly larvae providing 100% control till 7 and 10 days after spray [59,60]. The juvenoid diofenolan severely hampers the normal growth, development and metamorphosis of PDL and causes several deformities like delay in larval-larval and larval-pupal ecdysis, ecdysial failure, mortality, severe reduction in pupation, deformed pupae and complete inhibition of adult emergence [61].

Lewis [18] investigated and stated that Methionine caused 100% mortality in first through fourth instars of Heraclides (Papilio) cresphontes, and therefore may be a candidate environmentally safe bio-rational pesticide for use against invasive PDL in the Americas.

CONCLUSION

Among the different *Papilio* species infesting citrus PDL was most prevalent and destructive pest in terms of its foliage damaging ability across the World. Lime Swallowtails initially have originated in Madagascar are native to Asia ranging Iran in the west across India and southern Chinato Japan and Australia in the east and extremely successful in the Asia greatly expanding its range within historic times. The main reason for its quick spread is its adaptability to various climatic conditions ranging from tropics to subtropics and part of the temperate regions, its habit of easy immigration and varied food habits. It adjusts itself to changing climates by adopting dormant pupal conditions. Similarly, the pest also adjusts it's food habit based on the availability of the food. PDL feeds on Fabaceae plants in Australia and on Rutaceae plants outside the Australia and Asia. PDL has the highest survival in the wet primary season (PWS), while the lowest survival was observed in the dry season (DS). And July to December is the most favourable period of its activity. For managing this pest the different biological agents infecting at different stages, various biocompatible and biodegradable bio-pesticides Like BTB, BTK, NSKE, azadirachtin, diofenolan, methonine etc., which interfere with the pests morphological and physiological aspects like feeding, moulting, cellular construction and cell immune system etc. without affecting the natural environmental balance were clearly reviewed in this paper. The overall effects of these natural bio-products offer a novel and only approach in integrated pest management programme in near future.

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Future thrust areas

In the management of lemon butterfly there is a plenty of scope for integrated pest management with bio-intensive approaches which is a present day option. The present research itself provides so many bio-management options with both bioagents and bio-pesticides, but it is needless to say that there should be a never ending search for still more potent bio-control agents' especially microbial agents can be identified collected, mass multiplied and their potency in field and laboratory is to be evaluated. Some of the new strains of BT may also be exploited. Only a few of the botanicals were tested against this pest. Hence some more research towards the botanicals usage to be concentrated. Another aspect still untouched is development of synthetic pheromones or colour oriented traps for adults, needs to be enthrusted in near future.

REFERENCES

1. Nayar K K Ananthakrishnan B V and David B V. General and Applied Entomology. TATA Mc Graw Hill Publishing Co. Ltd. New Delhi. 1976; pp - 486.
2. Ramasubbareddy K, Savitri P and Kameswar Rao P. Pest complex of citrus in Rayalaseema region. The Andhra Agric J. 1989;36(1):68-71.
3. Shivankar V J. Recent trends in insect pest management of citrus. Hi-tech citrus management: Proceedings of International Symposium on citriculture (Nov. 23-27) held at NRC for citrus, Nagpur, 1999; pp.773-774.
4. Singh SP. Species composition and diapause in citrus butterflies. J Insect Sci. 1993; 6: 48–52.
5. Resham BT, Fanindra PN, Butani DK. Insect pests of citrus in Nepal and their control. Pestology. 1986; 10(4): 24-27.
6. Guerrero, Veloz KAD, Boyce SL, BD Farrell. First New World documentation of an Old World Citrus pest, the lime swallowtail *Papilio demoleus* (Lepidoptera: Papilionidae), in the Dominican Republic (Hispaniola). American Entomol. 2004; 50: 227-229.
7. Thakare KR and Borle MN. Survey report of damage caused by lemon butterfly pest in Vidharbha region. Official communication vide D.O. No. 782/69 dt.26/08/1969.
8. Corbet AS and Pendleburry HM. The butterflies of the Malay Peninsula. 4th edition. Malayan Nature Society. Kuala Lumpur. 1992.
9. Atwal AS. Insect pests of citrus in the Punjab- Biology and control of citrus caterpillar *Papilio demoleus* L (Lepidoptera :Papilionidae). Punjab Hort J. 1964; 4(1): 40-44.
10. Butani DK. Insect pests of fruit crops- citrus. Pesticides. 1973; 7(12): 23-26.
11. Wehling W, Nunez CA and Glass berg J. Lime swallowtails in a New World. American Butterflies. 2006; 31-34.
12. Benyamini D, Bruschini C, Serra G and John E. First confirmed records of *Papilio demoleus* (Linnaeus 1758) in Syria, with comments on the species' appearance in Turkey and the Dominican Republic. News of the Israeli Lepidopterists Society. 2007; 24: 4-11.
13. Lewis, Delano S, Cuda, James P Stevens, Bruce R A. Novel Biorational Pesticide: Efficacy of Methionine Against Heraclides (Papilio) cresphontes, a Surrogate of the Invasive Princeps (Papilio) demoleus (Lepidoptera: Papilionidae). J Economic Entomol. 2011; 104(6): 1986-1990(5).
14. Evgueni V, Zakharov, Campbell R, David C, Lees, Alison Cameron, Richard I, Vane- Wright, and Felix A H Sperling. Independent gene phylogenies and morphology demonstrate a malagasy origin for a wide-ranging group of swallowtail butterflies. Evolution. 2004; 58(12): pp.176-195.
15. Eastwood, RG, Boyce S L and Farrell BD. The provenance of Old World lime swallowtail butterflies, *Papilio demoleus* (Lepidoptera: Papilionidae), recently discovered in the New World. Ann Entomolog Soc America. 2006; 99: 164-168.
16. Nakayama T and Honda K. Chemical basis for differential acceptance of two sympatric Rutaceous plants by ovipositing females of a swallowtail butterfly, *Papilio polytes* (Lepidoptera, Papilionidae). Chemoecol. 2004; 14: 199–205.
17. Rothschild W and Jordan K. A revision of the American Papilios. Novit Zool. 1906; 13: 411-752.
18. Lewis, C B. New swallowtail butterfly. The appearance of *Papilio andraemon* in Jamaica. Natural History Notes of the Natural History Society. 1946; 25: 15.
19. Visheshni Chandra, Takashi A Inoue and Uma R Khurma. The Distribution and Larval Host Plant of *Papilio schmeltzii* Webistem.com/Psi2009 output directory/cd1/articles/000208.pdf.
20. Matsumoto K. Establishment of *Papilio demoleus* L. (Papilionidae) in Java. J Lepid Soc 1996; 50: 139–140.
21. Narayanamma V L, Savithri P, Rao R. Influence of citrus butterfly *Papilio demoleus* L. damage on growth parameters of the sweet orange host plant. Indian J Plant Prot. 2001; 29: 140–141.
22. Bindra O S. Insect pests of citrus and their control. Indian J Hort. 1957; 14: 88-89.
23. Ramasubbareddy K. Surveillance of insect pests and natural enemies. All India Coordinated Citrus Improvement Project, Tirupati. Annual Report. 1986; pp.16.
24. Butani DK,Jotwani MG. Trends in the control of insect pests of fruit crops in India. Pesticides. 1975; 9(4): 139-149.

25. Usharani B, Vijayasamundeswari, A, Saraswathy S, Indra N, Parthiban S, Suresh K and Selvarajan M. Diversity of insect pests of acid lime in Tamilnadu. National Dialogue on Citrus Improvement, Production and Utilization (27-29, Feb) held at held at NRC for citrus, Nagpur. 2012; pp.246.
26. Lakshminarayanamma. Studies on seasonal occurrence, biology and control of citrus butterfly, *P. demoleus* Linnaeus (Papilionidae : Lepidoptera) M.Sc (Ag) thesis submitted to Acharya NG Ranga Agricultural University, Hyderabad. 200; pp 141.
27. Ram P, Pal RK, Singh J. Incidence of lemon butterfly, *Papilio demoleus* on citrus. Ann Plant Prot Sci. 2000; 8(2): 245-246.
28. Alturi JB, Ramana SPV, Reddi CS. Life history of *Princeps demoleus* (Lepidoptera:Rhopalocera: Papilionidae) from India. J Natl Taiwan Mus. 2002; 55: 27–32.
29. Shravan M Haldar, Karuppaiah V, Sharma SK, Singh R S. Population dynamics of lemon butterfly (*Papilio demoleus*) in Bael (Aegle marmelos) as influeenced by abiotic factors in arid regions of Rajasthan. Indian J Arid Hort. 2010; 5(1-2): 50-52.
30. Suwarno. Feeding preference of *Papilio polytes* L. Larvae on Rutaceous host plants. J Natural. 2010; 10(1): 21-26.
31. Yadav L B and Rizvi S M A. Studies on the insect pests of lime, *Citrus aurentifolia* Swing. In eastern Uttar Pradesh. Ann Plant Prot Sci. 1995; 3(1): 34-37.
32. Gopali J B, Sharanabasappa, Suhasyelshetty YK, Kotikal, Athani S I. Evaluation of eco friendly pesticides against citrus butterfly *Papilio demoleus*, L. on Kagzi lime *Citrus aurentifolia* Swingle. National Seminar on Recent trends in production technology and value addition in acid lime, Bijapur, Karnataka (Aug. 11-13). 2011; pp 113.
33. Nandni Durgesh, Raghuwanshi Arun and Shrivastava Vinoy Kumar. Life cycle, population index and feeding activities of the lime butterfly, *Papilio demoleus* (Lepidoptera: rhopalocera: papilionidae). Trends in Biosciences. 2012; 5(1):31-34.
34. National Horticulture Mission, Ministry of Agriculture, Department of Agriculture & Cooperation Krishi Bhawan, New Delhi, IPM Schedule for Citrus Pests, Extension Bulletin No. 4 , PP-19-20.
35. Keiichi Honda. Flavanone glycosides as oviposition stimulants in a papilionid butterfly, *Papilio protenori* J Chem Ecol. 1986; 12(10):1999-2010.
36. Saxena K N, Goyal S. Orientation of *Papilio demoleus* larvae to coloured solutions. Experientia Basel. 1978; 34(1): 35-36
37. Ramzan M and Darshan Singh. Record of *Pteromalus puparum* Linn. (Hymenoptera: Pteromalidae)from pupae of lemon butterfly, *P. demoleus* Linn. at Ludhiana. J Bombay Natural History Society. 1979; 75(3): 931-932.
38. Muhammad Ather Rafi. Bionomics of Citrus Butterfly, *Papilio demoleus* ; in rain fed ecology of Pakistan. VDM verlag Dr. Mullar (September 22)-Publisher. 2010; pp 100.
39. Maheswarababu P. Biology and chemical control of citrus butterfly *P. demoleus* Linnaeus (Papilionidae : Lepidoptera) M.Sc (Ag) Thesis submitted to Andhra Pradesh Agricultural University, Hyderabad. 1988; pp-117.
40. Tripathi D, Singh H M, Singh S B. Comparative biology of lemon butterfly (*Papilio demoleus* Linn.) on lemon(*Citrus limon* Burm.) and babchi (*Psoralea corylifolia*). Shashpa. 1998; 5(2): 137-140.
41. Delano S Lewis. Lime Swallowtail, Chequered Swallowtail, Citrus Swallowtail *Papilio demoleus* Linnaeus (Insecta: Lipidoptera: Papilionidae). ENY 444 Document. a series of the Entomology and Nematology Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, Extension. University of Florida. 2009.
42. Tiatula Jamir, Pankaj Neog, Chaturvedi DP. Studies on biology of lemon butterfly, *Papilio demoleus* (Lepidoptera :Papilionidae) and species composition at Dimapur District of Nagaland. National Dialogue on Citrus Improvement, Production and Utilization (27-29, Feb) held at held at NRC for Citrus, Nagpur. 2012; pp.245.
43. Krishnamurthy A, Singh SP. Record of the egg parasite, *Trichogramma chilonis* on *Papilio* spp.in citrus. Curr Sci. 1986; 55(9):461.
44. Krishnamurthy A and Singh S P. Observational studies on the occurrence of the parasitoids of *Papilio* Spp. in citrus. Indian J Plant Prot. 1988; 16(1):79-81.
45. Mani M, Krishnamoorthy A. Safety of Plant Products and Conventional Pesticides to *Distatrix papilionis* (Vireck) (Hymenoptera: Braconidae), A Parasitoid of Citrus Butterfly. Indian Journal of Plant Protection. 2000; 28(1).
46. Garraway E, Bailey A J A. Parasitoid induced mortality in the eggs of the endangered giant against swallowtail butterfly *papilio homerus* (papilionidae). J Lepidopterist's Soc. 1992; 46(3): 233-234.
47. Singh SB, Singh HM. Natural enemies associated with insect pests of lemon, *Citrus limon* Burm. Shashpa. 1998; 5(1): 109-110.
48. Suwarno. Age-specific life table of swallowtail butterfly *Papilio demoleus* (Lepidoptera : Papilionidae) in dry and wet seasons. Biodiversitas. 2012; 13(1), 28-33.
49. Solunke B R and Deshpande S V. Studies on use of plant products for the control of lemon butterfly larvae. J Maharastra Agric University. 1991; 16(2): 302-303.

50. Suyog pande, Pandey J P and Tiwari R P. Effect of some botanicals on haemocytes and molting of *Papilio demoleus* larvae. J Entomol. 2012; 9(1): 23-31.
51. Johnson K S, Scriber J M, Nitao J K, Smitley D R. Toxicity of *B. thuringiensis* var kurstaki to three non-target Lepidoptera in field studies. Environ Entomol. 1995; 24(2):288-297.
52. Ranjit Singh, Mahalakshmi R, Vijayachandran SN. The lemon butterfly : Potential pest of *Aegle marmelos* Corr. in nursery and its management with neem. Insect Environ. 1996; 2(3): 70.
53. Chauke R P, Pasalwas A N and Dalal S R. Efficacy of various insecticides and plant products against the larvae of lemon butterfly (*Papilio demoleus)*. Hi-tech citrus management: Proceedings of International Symposium on citriculture (Nov. 23-27) held at NRC for citrus, Nagpur. 1999; pp.928-930.
54. Sharma RN, Maharashi RP, Gaur RB. Management of stem end rot of *Citrus delisiosa* through bioagents. Ann Plant Prot Sci. 2009; 3: 34-37.
55. Hatim G Mardi, Rehab E Idriss, Mohannad Z Abdella and Omar A A Sid Ahmed. Effect of Nimbecidin® 0.03% and Agerin® on the larvae of lemon butterfly (*Papilio demodocus* Esper). J Sci Technol. 2009; 10(2):100-104.
56. Sadawaste A K, Giri GK and Jayawar NE. Biointensive management of citrus butterfly, *Papilio demoleus*, L. National seminar on citrus bio diversity for livelihood and nutritional security (4-5 Oct.) Nagpur, Maharastra. 2010; pp 393.
57. Gopali J B, Sharanabasappa, Suhasyel hettyYK, Kotikal, Athani S I 2011. Seasonal abundance of citrus butterfly, *Papilio demoleus*, L. and its parasitisation by natural enemies in north Karnataka on Kagzi lime. National Seminar on Recent trends in production technology and value addition in acid lime, Bijapur, Karnataka (Aug. 11-13), pp 113.
58. Fawzi AL –Zubaidi, Nasir A, Hilafy, Layla N, Al-Okaily. *Bacillus thuringiensis* var . kuristaki Berliner as a biological control agent against lemon butterfly , Papilio demoleus (Lepidoptera:Papilionidae). J Kerbala University. 2007;5(4):1-5.
59. Ramaiah M, et al. Management of citrus butterfly using *Bacilllus thuringiensis* in sweet orange Cv. Sathgudi. National seminar on Microbial Diversity and Bioprospecting-Exploring the Unexplored (25-26, March), held at SVUPGC, Kavali. 2010; pp-19.
60. Sarada G and Rao A R K. Management of Citrus butterfly using bio pesticides on sweet orange nursery. Ann Plant Protec.Sci. 20(2): 464-465.
61. Singh, Satya, Kumar, Krishna. Diofenolan: a novel insect growth regulator in common citrus butterfly, Papilio demoleus. Phytoparasitica. 2011; 39(3): 205-213
62. Asokan R. Mass rearing and an additional instar of *Papilio demoleus* L. on the acid lime, *Citrus aurentifolia* Swingle. Insect Environ. 1997; 2(4): 128-129.