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BIONOMIC STUDIES OF *PAPILIO DEMOLEUS* LINNAEUS, THE CITRUS BUTTERFLY, (LEPIDOPTERA: PAPILIONIDAE), FROM LOWER SINDH, PAKISTAN.

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ABSTRACT. Biological parameters of *Papilio demoleus* Linnaeus, the Citrus Butterfly, in Tando Muhammad Khan, lower Sindh, Pakistan are presented. This major agricultural pest was reared on *Murraya koenigii* (L.) Spreng. (Curry Leaf) and ten different varieties of *Citrus* sp. (Citrus) plants. The length of the adult mating period ranged 5 to 8 hours. Following mating, females laid 27.7 ± 3.3 eggs. Eggs hatched in 1.5 to 7 days. Mean durations of larval instars were 1.8 ± 0.1 (minimum) and 2.9 ± 0.1 (maximum) days respectively. Pupal duration was 5.5 to 20 days. Biotic factors including predators [praying mantis, ants, Common Garden Lizard (*Calotes versicolor*)] and parasitoids [*Trichogramma chilonis, Pteromalus puparum*] played a significant role in mortality in all stages of the butterfly. Survival in most life stages had a negative correlation with temperature. Thirteen generations of *P. demoleus* per year were recorded. The feeding effect of Curry Leaf and ten different Citrus varieties on butterfly survival was examined. The Growth Index value was highest on *Citrus aurantiifolia* (Kaghzi Lime) and lowest on *Murraya koenigii* (Curry Leaf). The effect of artificial diets on adults was studied; only a 15% honey solution increased fecundity rate and survival of the adults.

INTRODUCTION

Papilio demoleus Linnaeus, the Citrus Butterfly (also commonly known as the Lime Swallowtail), is a major pest of *Citrus* sp. (Citrus) and *Murraya koenigii* (Curry Leaf) plantations (Duport, 1913; Malik, 1970, Badawi, 1981). The butterfly has a wide ecological tolerance, enabling it to thrive in a broad variety of climatic conditions (Rafi *et al*., 1999d). It is found in much of southern Asia from Saudi Arabia east to Australia, New Guinea and the Philippines. More recently, it has been introduced into the Caribbean (Eastwood *et al.*, 2006; Guerrero *et al.*, 2004; Homziat and Homziak, 2006; Wehling *et al.*, 2007). Where it occurs, it is cosmopolitan in distribution (Srivastava and Ahlawat, 1999). In Pakistan, *P. demoleus* flies in all four provinces virtually year-round with greatest numbers observed from August through October (Roberts, 2001).

Citrus is a highly profitable fruit crop that grows between 40°N and 40°S latitude worldwide in more than 125 countries with an estimated annual production of 93.7 million tons (Srivastava and Ahlawat, 1999). In Pakistan, it is grown over an area of 197,021 hectares with an annual production of 1.9 million tons. Being a major export, it holds a pivotal position in the success of Pakistan's agricultural industry (Government of Pakistan, 1995). Curry Leaf is valued for its medicinal value, and its leaves are traditionally used as a spice in cooking (Wasif, 1991). Because of inadequate protection programs, pests and disease cause enormous losses to these plant crops every year. It is feared if suitable remedial measures are not initiated soon, these important agricultural enterprises may decline or even collapse in the near future.

This study presents essential aspects of *P. demoleus* bionomics to better understand its function as an agricultural pest. The study includes biological parameters such as mating behavior, oviposition, fecundity rate, length of life stages, number and duration of generations, and the effect of biotic and abiotic factors. Pest status is calibrated by a Growth Index on Curry Leaf and ten different varieties of Citrus plants.

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Natural enemies and survival rates at different life stages are determined. The effects of artificial diets on adults are noted.

MATERIALS AND METHODS

Bionomic studies of *Papilio demoleus* Linnaeus were conducted at Tando Muhammad Khan, lower Sindh (Pakistan). Eggs and larvae were first collected for this study in Citrus and Curry Leaf plantations in the vicinity of Karachi in 1998. Larvae were reared on *Citrus* sp. (Citrus) and *Murraya koenigii* (Curry Leaf) in plastic jars provided with fresh leaves of hostplants twice a day until pupation. Ten pairs of the resultant adult butterflies were released in January 1999 into a wood-framed cage measuring 10 x 15 x 10 feet in size. The cage was covered on four sides with #15 nylon mesh size, which allowed unimpeded air circulation. A single small entrance door was placed on one side. During the first (three-year) phase of the study (1999-2001), *Citrus aurantiifolia* var. 'Kaghzi Lime' and *Murraya koenigii* were planted inside the cage to serve as ovipositional substrates and larval hostplants. Plant height was constantly maintained at three feet. Seasonal flowering plants were provided as nectar sources for adult butterflies. In addition, a supplemental 15% honey solution was sprayed at regular intervals on flowering plants inside the cage.

All cages were thoroughly examined each day to record observations and to check for immatures. Data were collected regarding survival rate, pre-mating behavior, mating period, pre-oviposition, oviposition period, fecundity rate and incubation period. All the observations were taken continuously during 13 daytime hours daily from 6:00 A.M. to 7:00 P.M. Ambient temperature was recorded frequently. Parasites and predators of all infested stages were preserved and identified at the Entomology Section of the Department of Zoology, University of Karachi.

The next generation was maintained in similar conditions. This study group was initiated using ten random pairs of adult butterflies bred from eggs of the first generation and released into a second similar cage. This process was repeated for thirteen generations over the course of each year, alternating the use of two cages. Observations were continued through the duration of the three-year period 1999-2001. Survival data of 39 generations of *P. demoleus* were analyzed for each life history stage (egg, larva, pupa and adult), including calculation of mean and standard deviation (S.D.).

The second phase of this study was conducted in 2002. Ten pairs of adult butterflies (originating from the last generation of the previous year) were released in January into the wood-framed cage, with subsequent generations alternating between two cages. During this phase of the study, *Murraya koenigii* and ten Citrus varieties were planted inside the cages to serve as ovipositional substrates and larval hostplants. The Citrus varieties used were: *Citrus aurantiifolia* (Christmann) Swingle var. 'Kaghzi Lime' (Kaghzi Lime), *Citrus aurantiifolia* var. 'Sweet Lime' (Sweet Lime), *Citrus aurantium* Linnaeus var. 'Khatta' (Khatta Orange, Sour Orange), *Citrus limon* Linnaeus var. 'Eureka' (Eureka Lemon), *Citrus limonia* Osbeck (Common Jambhiri), *Citrus medica* Linnaeus (Citron), *Citrus reticulata* Blanco var. 'Coorg' (Sangtra Coorg Mandarin), *Citrus reticulata* Blanco var. 'Kinnow' (Kinnow Sangtra), *Citrus reticulata* Blanco var. *salicifolia* (Citrus Willow, Willow-leaved Mandarin), and *Citrus sinensis* Linnaeus var. 'Washington Navel' (Washington Navel Orange). Potted plants, five of each variety, were placed 1½ ft. apart within the cage. Plant height was constantly maintained at three ft. Seasonal flowering plants were provided as nectar sources for adult butterflies. In addition, a supplemental 15% honey solution was again sprayed at regular intervals on flowering plants inside the cage.

After release of ten pairs of adult butterflies, each plant was closely observed to record ovipositional preferences. The number of eggs deposited on each variety of plant was recorded. Ten first instars of each

generation were transferred to separate plastic jars and provided with respective host plant leaves twice a day. Larval growth rates and survivorship were noted. This protocol was repeated for each of thirteen generations over the course of the year. The Growth Index (N x 1/T) was calculated for developmental stages of *P. demoleus* on the selected hostplants. [N = % larvae reaching maturity; T = mean larval period]

The third phase of this study was conducted in 2003. Ten pairs of adult butterflies (originating from the last generation of the previous year) were released in January into each of three separate wood-framed cages, with subsequent generations alternating between two sets of cages. During this phase of the study, *Murraya koenigii* and ten varieties of Citrus plants were similarly utilized inside the cages to serve as ovipositional substrates and larval hostplants. Three adult diets consisting of 15% solutions of honey, sucrose and glucose respectively were tested in each cage. These solutions were sprayed at regular intervals on flowering plants in the cage. The effect of each diet on pre-oviposition period, fecundity rate and longevity was noted. Larval success of this generation was noted on *Murraya koenigii* and the ten Citrus varieties.

RESULTS

Immature Stages

Egg (Figs. 1 & 2). Egg round with a smooth and glistening surface. Color yellowish-green. Part of the egg glued to the plant is flat. Slowly turns brown before hatching (Fig. 2). Fertile eggs with prominent reddish-brown micropyle. Females lay eggs on young leaves, petioles, shoots, thorns and flowers of Citrus; most females prefer to deposit eggs on both sides of the leaves. Mean egg diameter 1.1 mm. Larva. **First instar** (Figs. 3 & 4). Neonate larva emerges from egg by small lateral hole. Fully emerged larva usually eats the empty eggshell. Body color light brown; head brown to yellowish-white. Prothorax light yellowish-brown. Yellowish to milky white patch covers 3^{rd}-5^{th} abdominal segments. Abdominal 8^{th}-9^{th} segments yellowish-brown. Remaining segments with darker rings speckled with black patches. Head narrower than the thorax; remainder of body tapers. Larval cuticle with dark brown spines, which arise directly from the body on either side of a mid dorsal line. Length 3.5 mm. Width 0.7 mm (mesothorax) and 0.4 mm (9^{th}-10^{th} abdominal segments). A faint bird-dropping pattern appears in this instar; the camouflage is much more developed in the second through fourth instar. **Second instar** (Fig. 5). Body color dark brown. Head brown. Prothorax yellowish-brown. Prominent dorsal yellowish to milky white patch ("saddle") on the 3^{rd}-4^{th} abdominal segment; extends anterolaterally to 2^{nd} abdominal segment. Abdominal 8^{th}-9^{th} segments brownish yellowish. Spines as in the first instar. Length 7.5 mm. Width 1.8 mm (mesothorax) and 0.8 mm (9^{th}-10^{th} abdominal segments). **Third instar** (Fig. 6). Body color dark brown. Head brown. Prothorax yellowish brown with some milky white markings on the lateral side. Prominent dorsal white marking on 3^{rd}-5^{th} abdominal segment; runs obliquely and laterally on either side of the 2^{nd} abdominal segment and extends to 6^{th} abdominal segment. Pair of small lateral white patches on each side of 7^{th}-8^{th} abdominal segments. Prolegs yellowish brown. Nine pairs of spiracles on lateral side of abdominal segments; one on lateral prothorax. Number, structure, color and position of spines same as second instar. Length 13.5 mm. Width 2.4 mm (mesothorax) and 1.5 mm (9^{th}-10^{th} abdominal segments). **Fourth instar** (Fig. 7). Similar to previous instar except size. Body color dark brown. Head brown. Prothorax yellowish brown with lateral milky white markings extending to 1^{st} abdominal segment. Two broad black patches laterally on either side of 2^{nd} abdominal segment and small white markings laterally at the base of the prolegs on 3^{rd}-6^{th} abdominal segments. White lateral patches on the 7^{th}-8^{th} abdominal segments. Number, structure, color and position of spines same as third instar. Length 19.0 mm. Width 4.1 mm (mesothorax) and 2.2 mm (9^{th}-10^{th} abdominal segments). **Fifth instar** (Fig. 8). Body color green to yellowish green. Milky white venter and lateral line. Head light brown. Prothorax green with small brown tubercles. Two dorsal black bands between meso-metathorax and 1^{st}-2^{nd} abdominal segments. Small eyespot on dorsolateral metathorax. Oblique lateral brown patches on 4^{th} and 5^{th} segments. Minute black spots on

anterior parts of the 3rd-7th abdominal segments, sometimes absent. Last abdominal segment with two terminal brown spines. Body smooth without any branching spines. Length 39.5 mm. Width 9.4 mm (mesothorax) and 5.50 mm (9th-10th abdominal segments). **Note:** After each molt, larvae commonly eat exuviae except for hard sclerotized parts. Larvae rest approximately 30-45 minutes as new cuticle hardens.
Pupa (Figs. 9-11). Pupation occurs 2-5 meters from the host plant. Sites vary and include netting, pipes, wood structures, potted plants and pots. In prepupal phase, larva forms silk pad on substrate to which anal prolegs are anchored. A silk girdle is formed, passing over the metathoracic region and holding the prepupa in position (Fig. 9). The prepupal period lasts 1-2 days. At the end of this period larval skin is shed. Pupal skin takes approximately 40-70 minutes to harden. Pupal color yellowish green (Fig. 10) or light brown (Fig. 11). Head region with two frontal projections. Small dorsal tubercles on each abdominal segment. Pupae become transparent as eclosion nears. Length 30.2 mm. Width 9.8 mm.

Adult
Body color black dorsally, white ventrally with black stripes. Wings black, heavily patterned with irregular white marks. Hindwings lack tails. Red spot at anal angle, capped with a blue-black spot and light blue iridescent crescent. Blue-black spot and crescent often absent in males (Fig. 12), but prominent in females (Fig. 13). Wing color becomes a dull brown with age. Mean wing expanse (spread forewings apex to apex) of males 80.1 mm (n=10) and females 93.8 mm (n=10).

Duration of Life Stages
Thirteen generations were recorded as overlapping broods during the course of a year. The duration of the different generations was sensitive to ambient air temperature and varied from 22.5 to 46.5 days depending upon season. Cool-season generations were the longest-lived. Mean temperatures ranged from 17.5 to 38.0°C during different seasons with coolest temperatures in December-January and highest in March-July. Duration of immature life stages varied as follows: egg (1.5-7.0 days), larva (8.0-14.5 days), pupa (5.5-20.0 days). Mean durations of larval instars were 1.8 ± 0.1 (minimum) and 2.9 ± 0.1 (maximum) days respectively. Adult longevity averaged 4.9 days for the males and 6.7 days for the females over thirteen generations.

Mating and Oviposition
The pre-mating period began immediately after emergence, lasting 4-10 hours at an air temperature range of 15.9-37.0°C. Mating period lasted 5-8 hours. Females were observed to mate only once during their adult lifespan. After mating, females typically delayed oviposition for 23-40 hours. Deposition of all eggs was completed within 33-54 hours. Oviposition occurred between 8:00 A.M. to 6:00 P.M. The number of eggs deposited per female ranged from 13-40 with a mean of 27.7 ± 3.3.

Survival and Mortality of Immature Stages
Mortality rates for immature stages of all 13 generations were as follows: eggs (22.7 ± 4.4%), 1st instar (22.9 ± 8.3%), 2nd instar (15.7 ± 5.9%), 3rd instar (14.0 ± 5.5%), 4th instar (20.4 ± 5.4 %), 5th instar (16.7 ± 5.1%), and pupa (27.0 ± 8.8%). The high rate of egg mortality was due to infertility, falling off leaves, predators (ants, praying mantis) and the parasitoid *Trichogramma chilonis* (Ischii) [Hymenoptera: Trichogrammatidae]. The larval mortality rate was primarily due to falling off leaves and predation by ants and the Common Garden Lizard (*Calotes versicolor* (Daudin) [Reptilia: Squamata: Agamidae]). Pupal mortality was primarily due to predation by the Common Garden Lizard and the hymenopterous parasitoid *Peteromalus puparum* (L.) [Hymenoptera: Pteromalidae].

Figs. 1-11. Immature stages of *Papilio demoleus* from lower Sindh, Pakistan.

Fig. 1. Fresh egg.
Fig. 2. Mature egg.
Fig. 3 & 4. First instar larva.
Fig. 5. Second instar larva**.**
Fig. 6. Third instar larva.
Fig. 7. Fourth instar larva.
Fig. 8. Fifth instar larva.
Fig. 9. Pre-pupa.
Fig. 10. Pupa (green).
Fig. 11. Pupa (brown).

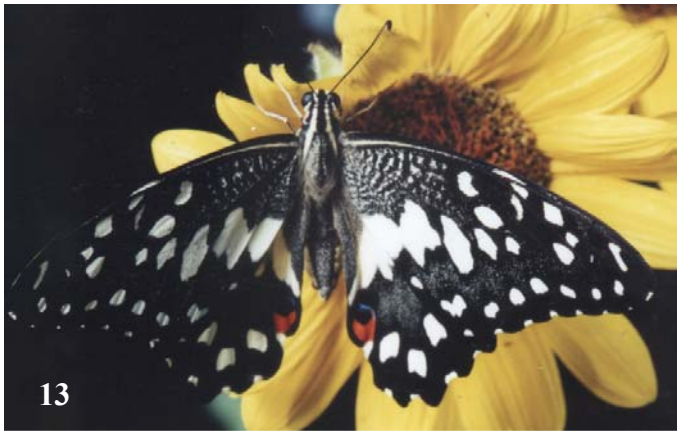

Fig. 12-13. *Papilio demoleus* adults from Lower Sindh, Pakistan. **Fig. 12.** Male. **Fig. 13** female.

Host Plant Preference

The host preference of *P. demoleus* was documented by counting the number of eggs laid on *Murraya koenigii* and on each variety of Citrus. Plants with a large number of new leaves usually had a higher mean number of eggs laid by females (Table 1). The data presented in table demonstrates that *Citrus aurantiifolia* var. 'Kaghzi Lime' recorded the highest Growth Index (G.I.) value of 13.8, followed by 12.3 for both *Citrus reticulata* var. *salicifolia* and *Citrus limonia*. *Citrus sinensis* and *Citrus medica* recorded the lowest G.I. value of 4.00 among *Citrus*, while *Murraya koenigii* recorded the lowest G.I. overall of 1.8. On the basis of G.I. value, the host preference of *Papilio demoleus* is as follows, in decreasing order: *Citrus aurantiifolia* (Kaghzi Lime) > *Citrus limonia* (Common Jambhiri) > *Citrus reticulata* var. *salicifolia* (Citrus Willow) > *Citrus aurantiifolia* (Sweet Lime) > *Citrus aurantium* (Khatta Orange) > *Citrus reticulata* (Kinnow Sangtra) > *Citrus reticulata* (Sangtra Coorg Mandarin) > *Citrus limon* (Eureka Lemon) > *Citrus medica* (Citron) > *Citrus sinensis* (Washington Navel Orange) > *Murraya koenigii* (Curry Leaf).

Scientific Name	Common Name	Mean Number Eggs Per Female	Total Number of Larvae	Mean Larval Period (days)	Number of Larvae Pupated	Mean Pupal Period (days)	Number of Adults Eclosing	Number of Adult Males	Number of Adult Females	Growth Index (G.I.) Value	Survival Rate
Citrus aurantifolia var. 'Kaghzi Lime'	Kaghzi Lime	20.6	10	6.5	9	6.0	9	3	6	13.84	90%
Citrus reticulata var. *salicifolia*	Citrus Willow	19.8	10	6.5	8	6.0	8	3	5	12.30	80%
Citrus limonia	Common Jambhiri	17.6	10	6.5	8	7.0	8	2	6	12.30	80%
Citrus aurantium var. 'Khatta'	Khatta Orange	14.4	10	7.0	7	6.0	7	3	4	10.00	70%
Citrus aurantifolia var. 'Sweet Lime'	Sweet Lime	13.4	10	7.0	7	6.0	7	3	4	10.00	70%
Citrus reticulata var. 'Kinnow'	Kinnow Sangtra	11.8	10	7.5	6	8.0	5	2	3	8.00	50%
Citrus reticulata var. 'Coorg'	Sangtra Coorg	11.6	10	7.0	5	7.0	4	2	2	7.14	40%
Citrus limon var. 'Eureka'	Eureka Lemon	11.4	10	7.0	5	9.0	4	2	2	7.14	40%
Citrus sinensis var. 'Washington Navel'	Washington Navel Orange	11	10	10.0	4	8.0	3	1	2	4.00	30%
Citrus medica	Citron	10.8	10	10.0	4	7.0	3	1	2	4.00	30%
Murraya koenigii	Curry Leaf	10.4	10	11.0	2	8.5	1	1	0	1.82	10%

Table 1. Female Ovipositional Preference and Growth Index (G.I.) value of developmental stages of P. demoleus on selected hostplants during 2002.

Natural Enemies

A field survey of natural enemies of *P. demoleus* conducted at various Citrus orchards found that in general birds were the most important predators during larval stages, especially 2nd instar to 5th instars. Birds also attacked adults. Wild eggs in the field infested by the parasitoid *Trichogramma chilonis* were noted. Predator ants (black, brown), praying mantises, and Common Garden Lizards were common in the field.

Influence of Artificial Diets

Adult *P. demoleus* females while being fed a 15% honey solution laid a larger proportion of their eggs (27.7%) in contrast to females being fed 15% sucrose solution (12.4%) and 15% glucose solution (13.3%). Adult longevity was 4.5-5.0 days (males) and 5.0-7.0 days (females) while being fed a 15% honey solution. This was empirically better than adult longevity rates of 3.0-4.5 days (males) and 3.0-4.0 days (females) on 15% sucrose solution, and of 3.0-4.0 days (males) and 3.0-4.5 days (females) on 15% glucose solution.

DISCUSSION

We found the egg incubation period of *P. demoleus* was 1.5–7.0 days over the range of seasonal ambient temperatures in Pakistan. This range spans the variable reported ranges in the literature, specifically 2-9 days in Mushtaque (1964), 3-6 days in Mishra and Pandey (1965), 4-5 days in Badawi (1968), 3-6 days (Abu-Yaman, 1973), 3.8-8.9 days (Farahbakhsh and Khashkooli, 1978), 3.1-6.1 days (Badawi, 1981), 2-3 days in Winotai and Napompeth (1981), 3-6 days in Radke and Kandalkar (1989), 4-5 days in Rafi *et al*., (1989), 2.4-3.5 days in Rafi *et al*. (1999c), 1.5-4.5 days in Rafi *et al*. (1999d), and 3.2-4 days in Atwal (1976).

We have determined that there are five larval instars, similar to that reported by Ghosh (1914) and Mushtaque (1964), but differing slightly from Badawi (1981) who reported 5-6 larval instars. In our study the duration of the larval stage (8.0-14.5 days) was found to be shorter than ranges reported in the literature, specifically 13-26 days by Mishra and Pandey (1965), 12-34 days by Badawi (1968), 18-25 days by Sharifi and Zarea (1973), 11-31 days by Badawi (1981), 16 days (Rafi *et al*., 1989) and 11-30 days by Rafi *et al*. (1999d). The longer periods were reflective of cool-weather larval development.

We found the length of the pupal stage (5-20 days) to be similar to that reported in the literature, specifically 18 days in Rafi *et al*. (1989), 7-21 days in Rafi *et al*. (1999d), 11.7 days in Badawi (1968, 1981), and 9.4-12.2 days in Sharifi and Zarea (1970). Sharifi and Zarea (1970) reported that the pupal stage of *P. demoleus* is very sensitive to temperature. Even though they hibernated in winter, any rise in temperature above 25˚C caused adults to emerge. The same results were observed during present study. Talbot (1939) reported that greenish pupal color was due to pupal development in proximity to leaves or any other green object, and brown pupal color was due to proximity to brown objects. Our observations support these findings. Tauber *et al*. (1986) reported that pupal polymorphism does not affect rate of development of the adult.

Ants are major predators of *P. demoleus* eggs and young larvae. Owen (1971) described that 90% eggs are eaten by ants. Jalali & Singh (1990) and Weeravit-Vittayaluk (1991) recorded *Trichogramma* sp. and *Telenomus* sp. as egg parasitoids. The Common Garden Lizard (*Calotes versicolor*) voraciously attacks young and older larvae. Pupae are often infested by the hymenopterous parasitoid (*Pteromalus puparum*). Abu-Yaman (1973) from Saudi Arabia, Pipatwatankul (1979) and Napompeth (1981) from Thailand, and Rafi *et al.* (1999a) from Pakistan report that a majority of *P. demoleus* pupae are attacked by *Pteromalus puparum* parasite. Rafi *et al.* (1989) suggest that *P. puparum* may be the biggest limiting factor on *P.*

demoleus population buildup in Pakistan.

P. demoleus adults are very strong and survive in all seasons in lower Sindh. Males are swift fliers and disperse over a wide area; females tend to fly nearer to the host plants. We found that adults live 4-7 days, with males averaging 4.9 days and females 6.7 days. Reported ranges in the literature include 1-2 days in (Ghosh (1914), 5-12 days in Abu-Yaman (1973), 6.21 [mean] days in Farahbakhsh and Khashkooli (1978), 5.12 [mean] days in Badawi (1981), approximately 7 days in Rafi *et al*. (1989), 3.5-7.5 days in Rafi *et* al. (1999d), and 4-10 days (mean 6 days) in Winotai and Napompeth (1981). Rafi *et al*. (1999c) reported the premating period lasting 6-11 hours, which closely approximates the 4-10 hours observed in the present study. An earlier study conducted by Sharifi and Zarea (1970) reflected these results but some pairs of adults reportedly delayed mating for 1-2 days after emergence. In this study, the mating period was observed to last 5-8 hours, which is considerably longer than that reported in literature. Sharifi and Zarea (1970) reported mating to last 107 $\pm$ 35 minutes, while Rafi *et al*. (1999c) reported mating to last from 20 minutes to 1 hour and 5 minutes. Atwal (1976) reported that female *P. demoleus* normally mate only once in their lifetime. The same observation was made in this study.

Our study also confirmed the reports of Sharifi and Zarea (1970) and Rafi *et al.* (1999c) that mated females usually start to deposit eggs within two days, while Rafi *et al*. (1989) reported 2-3 days. Sharifi and Zarea (1970) reported the oviposition period to last 1-4 days, while Winotai and Napompeth (1981) report that oviposition took place over a period of 2-6 days. In our study, females completed oviposition within 33-54 hours (1.4-2.2 days), which closely approximates the 35-60 hours (1.5-2.5 days) reported by Rafi *et al*. (1999c). Sharifi and Zarea (1970) reported that *P. demoleus* females laid 7-75 eggs with a mean of 31 egg per females; Farahbakhsh and Khashkooli (1978) likewise reported females deposited 12-77 eggs with an average of 38.2. Pipatwatankul (1979) reported oviposition with a mean of 96.7 $\pm$ 31.1 eggs. Rafi *et al*. (1999c) reported 10-45 eggs with a mean of 26.8 $\pm$ 13.4. In our study the females deposited 13-40 eggs with a mean of 27.7 ± 3.3. Interestingly, Winotai and Napompeth (1981) reported a larger range of eggs (85-240) per female, but this was observed under controlled lab conditions. Sharifi and Zarea (1970) reported that oviposition took place between 9 A.M. and 4 P.M., while Rafi *et al.* (1999c) reported that oviposition took place between 9 A.M. and 5:30 P.M. In the present study *P. demoleus* oviposition took place in daylight between 8 A.M. and 6 P.M.

Maxwell-Lefroy (1906) reported that *P. demoleus* was active throughout the year and there were several generations. We found 13 generations per year in lower Sindh, each lasting 22.5-46.5 days. In the northern rain fed area of Pakistan, Rafi *et al.* (1999d) reported 8-9 generations (each lasting 26-167 days depending on season) with hibernating pupae lasting from November through March. In Iran, Farahbakhsh and Khashkooli (1978) reported 4-5 generations per year. Wynter-Blyth (1957) reported *P. demoleus* is found in large numbers during and after the monsoon in India and flies in all the seasons except when the winter is very cold. Our study found similar patterns and abundances. Pupae will hibernate during the coldest days of December and January.

Papilio demoleus is a major pest of the plant family Rutaceae (Fletcher, 1917; Pipatwatankul, 1979; Khan, 1940; Atwal, 1976) and can breed on all varieties of wild and cultivated Citrus. In the present study 10 different varieties of Citrus and Curry Leaf were evaluated as hostplants. The growth index value (G.I.) was highest on *Citrus aurantiifolia* (Kaghzi Lime) followed closely by *Citrus reticulata* (Citrus Willow) and *Citrus limonia* (Common Jamberi). *Citrus sinensis* (Washington Navel Orange) and *Citrus medica* (Citron) had the lowest levels among the Citrus. The lowest G.I. value overall was recorded on *Murraya koenigii* (Curry Leaf). Singh and Gangwar (1989) reported different Citrus affect the growth rate for *P. demoleus* in India. They found the G.I. value was highest in *Citrus reticulata*, followed by *Citrus madurensis*, and was

least in *Citrus medica*. Adult longevity was highest on *Citrus reticulata*. Rafi *et al*. (1999b) reported in their field trial of 11 different *Citrus* species and varieties that ovipositing wild females showed a decided preference for *Citrus aurantium* and *Citrus reticulata*. Females in this study showed similar preference for these two Citrus hosts. Furthermore, in our experience, plants with greater density of tender leaves had a higher number of eggs.

Adult swallowtails feed on a variety of food sources such as nectar and pollen (Boggs and Gilbert, 1979; Nishida *et al*., 1987). Under experimental conditions, butterflies fed sugar solutions increase longevity and/or egg production Stern and Smith (1960), Arms *et al*. (1974), Morton (1991), Watanabe (1992). In the present study, our results show empirical trends indicating adults live longer and lay more eggs while being fed 15% honey solution. This "natural" solution of sugars and amino acids produced better results than 15% sucrose solution and 15% glucose.

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