BIOLOGY AND BIOMETRIC STUDIES ON *Apis cerana indica* F. AND *Apis mellifera ligustica* Spin.

By

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I hereby declare that this thesis entitled "**Biology and biometric studies on *Apis cerana indica* F. and *Apis mellifera ligustica* Spin.**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

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INTRODUCTION

1. INTRODUCTION

Apiculture, the art and science of rearing honeybees for the produces they give, *viz*., honey and bees wax, has been practiced in a primitive form from time immemorial. However, commercial exploitation started only a century ago.

Apiculture has been practiced in Kerala from very ancient times. Improved techniques of beekeeping came into existence in the erstwhile Travancore state from the year 1924, under the pioneership of YMCA*, Marthandam. Since then a number of apiaries have sprung up in all favourable localities and the number of beekeepers and the bee colonies showed a steady increase.

There were only 450 bee colonies and 220 beekeepers in Kerala during 1972 (Appendix 1). The total annual production of honey was as low as 900 kg. There was a gradual increase over the years and in 1989, a record production of 11.4 lakh tonnes of honey was achieved. At this glorious peak of honey production, there were 11.72 lakh bee colonies and 82,000 bee keepers. In 1991, a disastrous bee disease appeared in Balussery near Calicut and spread throughout the state destroying more than 95 per cent of the then existing Indian bee colonies in the state. As a result the honey production went down to just 17000 kg in 1991 and the number of bee colonies reduced to 12140.

* Young Men's Christian Association

Kerala Agricultural University in 1992 identified the elusive disease as Thai sac brood and being a virus disease there is no effective chemical control measure against it. One of the measures suggested to keep the disease away was to replace the *Apis cerana indica* F. colonies with Italian bees, *Apis mellifera* L. which were known to be resistant to this disease. Studies on its adaptability and performance in Kerala are in progress.

Practically no systematic research work had been conducted in Kerala on the biology and other basic aspects of *A. cerana indica*. Italian bee, *A. mellifera* being newly introduced species in the state, there were no earlier studies on it. The present studies were hence taken up to generate detailed basic information on the biology, biometrics, natural enemies and diseases of Indian and Italian bees under Kerala conditions.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

A brief review of research work done in other states of India as well as in other countries is presented below.

2.1 **Duration of developmental stages**

2.1.1 *Apis mellifera*

Nelson and Sturtevant (1924) observed the egg stage of the worker bee as three days and larval stage (up to the capping of the cell) as 4.5 to 5.5 days with an average of 5 days. Bertholf (1925) who investigated the metamorphosis of Italian bees in detail found that the egg stage was 3, 3 and 3 days, larval stage 5, 5 and 7 days and pupal stage as 8, 13 and 14 days in case of queen, worker and drone respectively. Philips (1928) reported that hatching of the eggs took three days in each of the three castes, the larval stage (up to the time of capping of the cell) 5.5, 6 and 6.5 days and pupal stage 7.5, 12 and 14.5 days in the queen, worker and drone respectively.

Abdellatif (1967) reported that the most favourable time for queen rearing at the Alexandria region was April to May due to better weather conditions and availability of sufficient bee pasturage. Farrar (1967) observed that workers hatched in 3 days, larvae were sealed in 5 days and adults emerged in 12 days. The development of drones took 24 days. Alfred (1969) in his studies on artificial rearing of queen found that pupation period lasted five days.

Vashishant (1992) studied the biology of *Apis mellifera* under Punjab conditions during five seasons, viz., winter, spring, summer, monsoon and autumn with 4, 7 and 10 bee frame strength colonies. The duration of egg stage of worker bee ranged from 2-2.4 days in summer to 2.49 days in winter. Minimum larval duration of 6.89 days was observed during autumn and highest of 8.76 days in summer. The pupal period was minimum during summer (6.33 days) and significantly higher in autumn (8.27 days) and winter (8.29 days). The total developmental period of worker bee in different seasons did not vary significantly (17.58 - 18.67 days) except during winter when it was the longest (18.67 days). In case of drones, the spring and autumn seasons had no significant effect on the egg , larval and pupal duration and the colony strength also had no effect on any of the developmental stages. Mean egg, larval and pupal durations were 2.28, 8.93 and 10.29 days respectively in autumn. The larval duration of drone bee was significantly lower in spring (8.93 days) than in autumn (9.66 days). The total developmental period of drone bees in spring (21.49 days) was significantly lower than that in autumn (22.46 days).

2.1.2 ***Apis cerana indica***

Ramachandran (1939) recorded that the life cycle of *A. indica* queen lasted for 15-16 days (3 + 5 - 6 + 7), that of workers as 19 days (3+4+12) and that of drones as 23 days (3 + 7 + 13). Khan and Singh (1947) reported that the egg stage generally covered three days, the larval period 5

days and pupal period 11-12 days. The whole life cycle was completed in 18-19 days. The duration of different stages in the drone bee was found to be 3, 6-7 and 14 days with the life cycle completed in 23-24 days. Kapil (1959) found that the egg stage of worker bees took an average 3.15 ± 0.0529 days, the larval stage 5.136 ± 0.181239 days and the pupal period 10.984 ± 0.1832 days.

Naim (1983) studied the biology of the queen. Egg stage took 3 days in all cases. The larval stage lasted for 5 days and the pupal stage took about 7-8 days. The total development was completed within 15-16 days.

Mehrotra and Bischt (1984) reported that the egg stage in the Indian bees lasted 72 hours. The larval stage of queen took 5 days, worker bee 4-5 days and drone 7 days. The pupal stages of queen lasted 7-8 days, that of worker 11-12 days and drones 14 days. Thus the whole cycle was completed in 16 days in case of queen, 18-20 days in worker bees and 24 days in drones.

2.2 **Rate of egg laying**

2.2.1 ***Apis mellifera***

Brood rearing activity of *A. mellifera* was studied by various workers with widely varying results. Sharma (1951) observed that the *A. mellifera* queens laid on an average 1500-2000 eggs per day during the peak of brood rearing activity. According to Whitehead and Shaw (1951) it was 5000-7500 eggs per day. Khalifman (1953) theoretically calculated

that on an average the queen did not lay more than 2000 eggs a day on the assumption that she spends a little over 40 seconds for laying one egg. As high as 67,375 capped cells (2450 square inches) giving 5614 eggs per day were reported by Franklin (1953).

In the book "The behaviour and social life of honey bees" Ribbands (1953) has reviewed the following works; Bertepsch (1860) counted 38,619 cells of brood at one time giving a daily rate of 1855 eggs. Further, he confined the queen on an empty comb for 24 hours and counted 3021 eggs during that period ; Dufour (1901) during his 21 day studies found a laying rate of 1627 eggs per day; Brunnish (1922) in similar studies on colonies of Swiss blacks noted a range of 970-1750 eggs per day and estimated from brood counts at frequent intervals, a total count of 90,000 to 1,50,000 eggs in an year; Merril (1924) found an average of 1,77,700 cells for Italian bees for the period from March to October giving an average of 1720 eggs per day, the maximum being 2030. Nolan (1926) counted sealed brood of 48 colonies over a 21 day period and found that the daily rate of egg laying ranged from 757 to 1518 eggs. He further found that a good colony in one season would lay 195000 eggs; Wilson and Milum (1927) found 42120 cells at one time averaging 2005 eggs per day; Bodenheimer and Nerya (1937) estimated that a total of 2,20,000 eggs were laid over 12 months in a Palestinian colony.

Farrar (1967) observed that the queen of *A. mellifera* laid up to 1500 eggs per day and 2,50,000 eggs per year. Approximately 95 per cent of the

typical hexagonal cells of the combs were worker cells (25 per square inch) and the remainder were drone cells (16 per square inch).

The brood rearing activity of the Italian honey bees was studied by Atwal and Goyal (1970) in the Punjab plains at Ludhiana. They observed that there was a steep fall in brood area in August although the colonies maintained their strength on 3-4 frames. During winter (December-January) the brood rearing was very much restricted. An improvement was noticed from February onwards although large scale brood rearing started only in March. There was a further rise in brood area in April and May and the maximum of 1870 square inches was recorded early in May.

The number of eggs laid by five *A. mellifera* queens for a period of one year was studied at Nagrota (Kangravalley, India) by Adalakha (1972) and their rate of egg laying per day was calculated to range from 871 to 1368 during maximum brood rearing activity (March-April). These studies indicated the more prolific nature of *A. mellifera* queens compared to *A. indica* queens. Hameed and Adalakha (1973) also compared the brood rearing activity of *A. mellifera* and *A. cerana indica* in the Kulu valley in Himachal Pradesh. During spring *A. mellifera* reared 38 per cent more brood than *A. cerana*.

Goyal (1978) observed the maximum population of *A. mellifera* colonies in Punjab plains in the month of May. The minimum population was recorded during August.

2.2.2 *Apis cerana indica*

Ramachandran and Mahadevan (1950) studied the brood rearing cycle at Coimbatore and found the brood area as 303 and 276.9 square inches or 11817 and 10799 cells of brood respectively in two thriving colonies at the peak of brood rearing season, giving a daily output of 591 and 514 eggs.

Sharma (1948) recorded up to 752 square inches of brood area (24816 cells) amounting to 1240 eggs per day during February at Lyllapur.

Sharma (1951) found that *A. cerana indica* queens were capable of laying a maximum of 700-800 eggs per day during the peak of the brood rearing season.

Sharma (1958) studied the brood rearing activity of *A. indica* in Lyllapur in plains and Katrain in the hills. Most active brood rearing period at the higher hills was during May and August to September. On the other hand August-September was the period of least brood rearing in the plains. The brood rearing was seen suspended from November and the activity was resumed during January - February in the coldest period of winter. There was practically constant brood rearing in the plains throughout the year. It was further observed that maximum egg laying rate was 606 and 833 eggs per day at Lyllapur and Katrain respectively.

Goyal (1978) recorded maximum population of *Apis cerana indica* F in the month of May (18,000 - 22,000 per hive) and minimum population during August (1500 - 2000 per hive).

Naim (1983) observed that the egg laying capacity of cerana queens ranged from zero to 980 eggs per day. According to Mehrotra and Bischt (1984) it was between 350 and 1000 eggs per day.

2.3 **Longevity of workers and drones**

2.3.1 *Apis mellifera*

2.3.1.1 **Workers**

It is important to know the average life span of workers in different seasons of the year to ensure maximum field force at the time of major honey flow. Free and Spencer-Booth (1959) reported that the longevity of individual worker bees varied tremendously at different times of the year and that the average expectation of life was 35 and 28 days in March and June respectively. Fukuda and Sekiguchi (1966) estimated the life span of spring, summer and autumn bees to be about 30-40, 25-30 and 50-60 days respectively. Fukuda and Sekiguchi (1966) prepared life tables for three seasonal cohorts, June bees, July bees and wintering bees. Most workers died 25-40 days after emergence and whole cohort had died after 50 days. Kumar (1972) could put mean longevity of *Apis mellifera* workers to be 41.36, 33.84 and 36.19 days for January, March and April born bees in the sub-temperate region of Himachal Pradesh.

Sharma and Garg (1984) studied the longevity of *A. mellifera* workers in summer, monsoon and post monsoon periods. Mean longevity for the June 2, July 4, July 28 and September 4 born bees were 28.46 ± 1.45, 37.075 ± 0.52, 35.504 ± 0.5 and 29.708 ± 1.01 days respectively.

Pradeep and Goyal (1992) studied the longevity of *A. mellifera* in summer and autumn periods at Ludhiana. Mean longevity of bees emerged on April 5 and October 3 was 28.8 ± 0.9 and 30.12 ± 0.95 days respectively, the difference between the longevity for the two periods was however not significant.

Vashishant (1992) found that the longevity of worker bees was highest (41.87 days) in winter and lowest (26.80 days) in monsoon. The longevity was significantly more in the higher bee strength colonies.

2.3.1.2 **Drones**

The longevity of drones was studied in Punjab by Vashishant (1992) and it was higher in spring (49.93 days) than that during autumn (42.77 days).

2.3.2 ***Apis cerana indica***

Studies relating to the longevity of workers and drones of Indian bees in India are lacking.

2.4 Natural enemies and diseases of honey bees

Honey bees like all other animals are susceptible to infectious diseases caused by bacteria, protozoa and virus. A few non-infectious diseases have also been noticed. Various parasites and predators also cause considerable damage to bees and brood during different seasons.

2.4.1 Mites as pests of honey bees

The parasitic mites are of great economic importance as they cause great damage to bee keeping industry. The most important mites

associated with honey bees are *Varroa jacobsoni, Tropilaelaps clareae* and *Acarapis woodi* (Naim, 1987).

2.4.1.1 ***Varroa jacobsoni***

This is a large, broadly oval mite visible to nacked eyes. It was first reported from Andhra Pradesh in India by Subhaprabha (1961) on *Apis cerana*. Later it was reported from Pusa and Delhi by Phadke *et al.* (1966). Reports from other parts of the country were also published (Gupta, 1967 : Punjabi and Saraf, 1969).

2.4.1.2 ***Tropilaelaps clareae***

It is a serious ecto-parasitic mite of bees. *T. clareae* was reported on *A. mellifera* from India by Atwal and Goyal (1971) and observed up to 80 per cent brood kill in late larvae. The first report *of T. clareae* infesting *A. cerana* in association with *Varroa jacobsoni* came from Burma and Pakistan (Delfinado and Baker, 1942).

2.4.1.3 ***Acarapis woodi***

There are four species of *Acarapis* viz., *A. woodi, A. dorsalis, A. externus and A. vagans. A. woodi* is considered as the most serious endo-parasitic pest of honey bees causing the commonly called acarine disease. Acarine disease was first reported from India on *A. cerana indica* by Singh (1957) and Milne (1957). It infests the tracheae of first thoracic spiracle where they suck haemolymph.

2.4.2 **Wax moths**

The combs of honey bees are seriously damaged as a result of infestation by two species of wax moths, *Galleria mellonella* (Greater wax moth) and *Achroia grisella* (lesser wax moth). The lesser wax moth is more prominent in Delhi (Ramachandran and Mahadevan, 1950).

Goyal (1978) compared *Apis mellifera* and *Apis cerana indica* in terms of tolerance to wax moth attack. He found that the wax moth did not flourish well in *A. mellifera* due to the presence of propolis mixed with comb wax and their attack was very rare. The *A. cerana indica* bees do not collect much of propolis and hence fall a ready prey to wax moth.

2.4.3 **Predatory wasps**

Several species of hornets, viz., *Vespa orientalis, Vespa auraria, V. basalis, V. cincta, V. ducalis and V. magistica* have been reported as predators on honey bees. *V. cincta* and *V. orientalis* appear to be common all over the country while other species have a restricted distribution. The peak predatory activity occurs in August - September in the Kashmir valley, Kangra valley (Himachal Pradesh) Pathankot (Punjab) and Pune (Maharashtra) (Kshirsagar and Mahindre, 1975).

2.4.4 **Other enemies**

A number of *Apis mellifera* colonies were introduced to India. These bees are reared near A. indica colonies. Ocada (1985) observed that in Thailand, *A. cerana* and *A. dorsata* caused considerable damage to the

colonies of *A. mellifera*. Londt (1993) reported Africo-tropican robber fly (Diptera, Asylidae) as a serious predator of *Apis mellifera*. Singh (1985) reported a new hymenopteran parasite, *Anthocephalus sp.* (Chalcididae) whose apodous maggatoid larvae develop in the body cavity of worker bees.

2.4.5 **Diseases of honey bees**

Indian honey bee *A. cerana indica* was virtually free of any disease till 1956 when disease was reported for the first time. Subsequently five other diseases in Indian bee *A. cerana indica* have been detected. Following is a brief account of the occurrence and present distribution of bee diseases in India.

2.4.5.1 **Brood diseases**

2.4.5.1.1 **American Foul Brood (AFB)**

It is caused by a bacterium, *Bacillus larvae* in the late larval stage. Singh (1961) reported the presence of AFB disease in Indian honeybees for the first time in the samples of diseased brood received from the state apiarist Jeolikot (U.P). But recurrence of its occurrence on Indian honey bee has not been reported so far. However no incidence of this disease has been observed so far on *A. mellifera* since its introduction and establishment in 1962.

2.4.5.1.2 **European Foul Brood (EFB)**

The causative organism of this disease, *Streptococcus pluton* infects larva in the early stages and has been reported once from some pockets of Maharashtra (Kshirsagar, 1983).

2.4.5.1.3 **Thai Sac Brood**

It was first observed in 1976 in Thailand in *A. cerana* causing 100 per cent mortality, and because of certain physico-chemical and serological properties this was identified as a new strain of sac brood virus called as Thai sac brood.

In India this disease appeared in some parts of Meghalaya and Assam in 1978 and by 1980 it had spread to U.P, Punjab and neighbouring states (Kshirsagar *et al.*, 1981). This disease was reported in Kerala for the first time by Jacob *et al.* (1992).

2.4.5.2 **Adult bee diseases**

2.4.5.2.1 **Nosema disease**

It is caused by a protozoa, *Nosema apis*. It was first reported from Uttar Pradesh in1974 and now it occurs in Himachal Pradesh, Jammu and Kashmir and Punjab. Its occasional occurrence was recorded from Assam and Nagaland.

2.4.5.2.2 **Clustering disease**

This new disease of *Apis cerana indica* was noticed first in Kashmir and Himachal Pradesh in the year 1971 (Shah and Shah, 1976). A virus

(AIV) was isolated from a bee sample from a colony with clustering disease in 1976 (Baily *et al.*, 1976).

Srikrishna and Bhagat (1982) reported that incidence of AIV was highest in April followed by May and June. Severity was less in October and November. A remarkable reduction was observed in February.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Studies on the biology of honey bees in relation to different seasons, viz., brood rearing season, honey flow season and lean season were carried out from September 1995 to August 1996 on bee colonies in the apiary of Kerala Agricultural University, College of Agriculture, Vellayani. (situated between 76, 59' 08" longitude, 80 24' 90" N latitude and at a mean height of 29 m above mean sea level). However, during honey flow season the experimental colonies were kept in rubber plantations in Nedumangad taluk (60 km away from the College). The yellow strain of Italian bee i.e., *Apis mellifera ligustica* Spin. and the Indian bee *A. cerana indica* were used in these studies.

3.1 **Development of worker and drone bees**

To start with five experimental colonies each from *A mellifera* and *A cerana* were selected at the beginning of the three seasons.

To observe the exact time of egg laying a fully raised comb with all worker cells was given at the centre of each colony. However, for the study of drones a comb having maximum number of drone cells was given to each colony during honey lean season and brood rearing season. The colonies were examined daily till the queen laid eggs in the cells of the marked frame. The approximate time of egg laying in each colony was

recorded and an area for worker caste measuring 6 x 6 cm and similarly an egg area of 7 x 7 cm for drone caste were marked for the developmental and biometric studies. For *A. cerana indica* an egg area of 5 x 5 cm and 4 x 4 cm were marked for respective castes. Each such worker brood area consisted of about 100 cells in *A. mellifera* and 120 in *A. cerana* whereas the number was about 85 and 105 respectively for drone brood area.

Five samples each containing five individual cells were identified on each marked area for studying the duration of various stages of different castes. The morphometric characteristics were studied by collecting five samples (eggs, larvae and pupae) at random at an interval of 24 hours from these marked areas till the adult emergence.

3.1.1 **Egg stage**

Five eggs were taken out daily from the marked area till their hatching. The size and colour of eggs were recorded. The eggs were measured under a microscope fitted with a calibrated ocular micrometer.

3.1.2 **Larval stage**

Five larvae were taken out daily from each of the experimental colonies. The size, colour and sequential development of larvae were recorded at an interval of 24 hours. Both the length and thickness of larvae were recorded with the help of the micrometer. The thickness was

measured at the centre of larvae. These observations were recorded till all the larvae had pupated.

3.1.3 **Pupal stage**

To study the pupal stage five pupae from each colony were taken out after removing the caps with the help of forceps from the marked area at an interval of 24 hours till adult formation. The size and colour of pupae were recorded. The length and thickness were measured with aid of the micrometer under the microscope. The thickness was measured at 4^{th} abdominal segment.

3.2 **Development of queen bee**

The development of queen bee was studied only during brood rearing season in *A. mellifera* and lean season and brood rearing seasons in the case of *A. cerana*. For this purpose four colonies each of *A. mellifera* and *A. cerana* were selected during the respective seasons. All the colonies for this experiment were dequeened on the same date. To record the exact date of egg laying, all the colonies were examined thoroughly for five days after dequeening and the queen cells found during this period were destroyed. This was necessary to have the colony free from the queens developing from the eggs or larvae of unknown age. This was taken up for five days because all the eggs and the young larvae from which a queen

could be developed would have passed their age, at which time the queen could be raised from them. Then queen bees collected from other colonies were released one each in the experimental colonies following recommended procedures. After these queens were observed to have started egg laying, all the experimental colonies were again dequeened immediately. When these cells were about to mature these were covered with queen cell protectors so that the first emerging queen could not destroy the other queen cells, there by facilitating the recording of emergence from all the cells under study.

3.3 **Rate of egg laying**

The egg laying rate (expressed as number of eggs laid per day) was calculated by measuring the brood area at an interval of 20 days (average life cycle of a worker bee from egg to adult). The area was measured by using a transparent sheet in which lines were drawn horizontally as well as vertically at a distance of one cm. Now each compartment would measure one square cm. This sheet was placed over the brood comb and number of squares covering the brood in all stages were recorded.

From the area occupied by the brood, the total number of cells was calculated. On an average 1 cm^2 brood area of *A. mellifera* contained four cells and *A. cerana* enclosed six cells. This figure was divided by 20 (the average time taken for the development worker bee from egg to adult) to give the average rate of egg laying. The formula used for the calculation is given below :

$$R = L \times B \times \frac{\pi}{4} \times \frac{X}{20}$$

R = Rate of egg laying

L = Length of the brood area in cm

B = Breadth of the brood area in cm

X = Number of cells per square centimeter.

For obtaining accurate values each brood area per comb was computed separately.

3.4 **Adult longevity**

The longevity of the worker bees was observed during monsoon and pre monsoon periods while that of the drones was recorded only during brood rearing season.

Adult longevity was determined by following a cohort of 100 freshly emerged and marked worker bees and 100 marked drone bees from each colony. Emergence cages having inner dimensions of 6 x 6.5 cm made of wire gauze having 11.6 mm mesh were used for getting the newly emerged bees from the respective colonies. These emergence cages were fitted to the brood, ready for adult emergence. Such combs were taken to laboratory next day and kept in incubator at 34^0C and freshly emerged bees were collected after removing the cages. The required number of bees were marked red on the thorax as described below. Good quality nail polish was used for this purpose. The bees were held gently between thumb and index

finger for marking on the thorax without causing any injury to the bees. A small spot of colour was applied on the thorax with the help of a fine camel hair brush. Such bees were then released into their respective hives after the colour dried up.

The marked workers were counted at frequent intervals at dusk, when all the bees had returned to hive. The first two observations were taken at weekly intervals. The third observation was taken three days after the second observation and then on alternative days and when the number of marked bees declined fast, the observations were recorded daily. The life span of each bee was calculated from emergence to the midpoint between the last day, the bees were observed and the next observation day. The mean life span of each cohort was calculated from these data.

3.5 **Recording of natural enemies**

This experiment was designed to study the seasonal incidence of various diseases and natural enemies associated with *Apis mellifera* and *Apis cerana indica* under Kerala conditions. Various techniques employed in this study are detailed below.

3.5.1 **Collection of debris**

The hive debris was collected on a white sheet of paper placed on the inner surface of the floor board overnight and brought to the laboratory for microscopic examinations.

3.5.1.1 **Examination of hive debris for mites**

A magnifying glass was used in locating the mites in the hive debris collected on paper sheets.

3.5.1.2 **Identification of bee mites**

All the mites collected were examined microscopically and identification was made with the help of available descriptions, illustrations, measurements and key to the identification.

3.5.2 **Sampling of colonies for pests, predators and natural enemies**

The infestation of pests and predators was recorded from the bee hives at weekly interval.

3.5.2.1 **Sampling of colonies for wax moth infestation**

The debris collected from honey bee colonies in different apiaries were also examined for the presence of different stages of wax moths throughout the year. Besides, live combs containing different stages of bees, nectar and pollen stores were also examined for the presence of eggs, larvae pupae and adults of wax moths. If any of the stage was found in debris or combs, the sample was considered to be infested. Based on this seasonal infestation was worked out. The debris on combs containing eggs of wax moth were kept in glass jars covered with muslin cloth and supplemented with wax from old combs as food for the developing larvae. They were reared under laboratory conditions (temperature 30-35^{0}C) for

adult emergence. Number of moths, larvae, pupae and adults of each species were counted per 100 g of debris as well as on infested combs and the number determined accordingly.

3.5.2.2 **Sampling of colonies for the presence of other pests**

The number of ants, honey feeding moths and other pests were counted and expressed as number per 100 g of debris.

3.5.2.3 **Observations on predators of honey bees**

Honey bees are attacked by various species of wasps and birds as well as by lizards and toads. For recording these predators weekly observations at two hourly intervals were recorded at three different times of the day throughout the year. The number of birds or wasps of each species visiting apiaries were recorded for 10 minutes during each observation period. Mean of these observation constituted reading for each month.

RESULTS

4. RESULTS

The results of the "Biological and biometric studies on *A. cerana indica* and *A. millifera*" are presented hereunder.

4.1 Duration of developmental stages

4.1.1 *Apis mellifera lingustica*

4.1.1.1 Worker

Results on the duration of developmental stages on *A. mellifera* are presented in Table 1 and illustrated in Fig. 1. The eggs hatched generally on the third day. Mean larval period ranged from 5.82 ± 0.101 days during lean season to 5.93 ± 0.131 days during honey flow and brood rearing seasons. The pupal period varied from 10.55 ± 0.33 days in brood rearing season to 11.15 ± 0.261 days during honey flow season. Total period to complete the development was 20.06 ± 0.313 days in honey flow season, 19.6 ± 0.242 days in lean season and 19.51 ± 0.278 days in brood rearing season.

4.1.1.2 Drones

Results presented in Table 2 and Fig. 2 reveal that the egg period ranged from 2.81 ± 0.379 days in lean season to 2.88 ± 0.063 days in brood rearing season. The larval period was minimum during brood rearing season (6.96 ± 0.187 days) and maximum during lean season (7.172 ± 0.162 days). The pupal period was 13.41 ± 0.395 days during brood rearing season and 13.282 ± 0.282 days during lean season. Total period of development worked out to be 23.53 ± 0.256 days (lean season) and 23.24 ± 0.403 days (brood rearing season).

Table 1 **Duration (in days) of the developmental stages of *Apis mellifera* workers**

Colony No.	Egg stage			Larval stage (upto capping of cells)			Pupal stage			Total developmental period		
	Brood rearing season	Honey flow season	Lean season	Brood rearing season	Honey flow season	Lean season	Brood rearing season	Honey flow season	Lean season	Brood rearing season	Honey flow season	Lean season
1	3.03	2.98	2.87	5.92	5.78	5.63	10.38	10.66	11.38	19.30	19.46	19.25
2	2.96	3.02	2.90	5.82	5.87	5.83	10.85	11.36	10.85	19.56	20.32	19.55
3	2.95	3.03	3.00	6.02	6.03	5.86	11.03	11.36	10.96	20.02	20.03	19.53
4	2.95	2.98	3.00	5.79	5.83	5.90	10.32	11.12	11.16	19.35	20.25	19.66
5	3.13	2.92	3.00	6.00	6.13	5.90	10.16	11.26	11.16	19.40	20.22	20.00
Mean ± SD	3.00 ± 0.069	2.97 ± 0.039	2.95 ± 0.057	5.93 ± 0.092	5.93 ± 0.131	5.82 ± 0.101	10.55 ± 0.333	11.15 ± 0.261	11.10 ± 0.183	19.51 ± 0.278	20.06 ± 0.313	19.60 ± 0.242

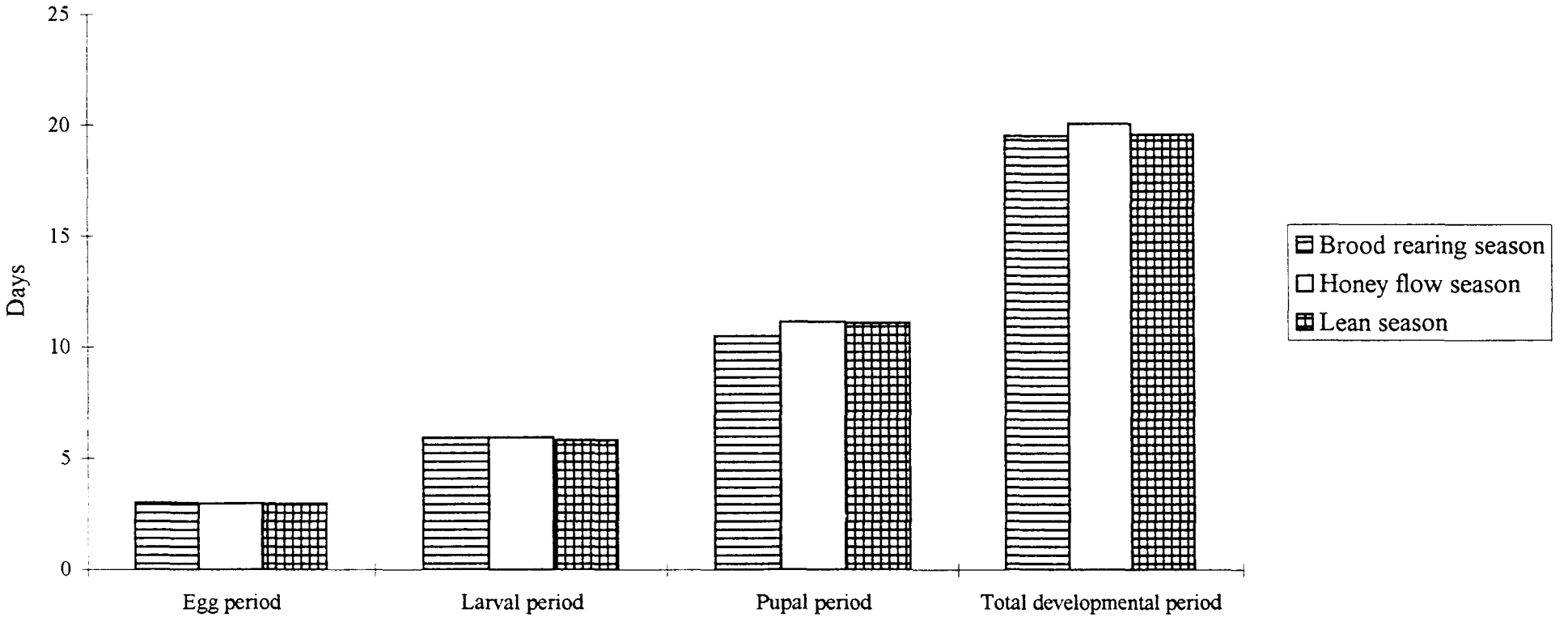

Fig. 1 Duration of the developmental stages of *A. mellifera* workers in different seasons

Table 2 **Duration (in days) of the developmental stages of *Apis mellifera ligustica* drones**

Colony No	Egg stage		Larval stage		Pupal stage		Total developmental period	
	Brood rearing season	Lean season	Brood rearing season	Lean season	Brood rearing season	Lean season	Brood rearing season	Lean season
1	2.85	3.05	6.60	7.13	13.80	13.38	23.25	23.55
2	3.00	3.00	7.05	7.20	13.95	13.45	24.00	24.00
3	2.85	2.95	6.98	6.90	13.25	13.60	23.08	23.45
4	2.83	2.05	7.15	7.40	13.05	12.78	23.03	23.23
5	2.85	2.98	7.00	7.35	12.98	13.20	22.83	23.43
Mean ± SD	2.88 ± 0.063	2.81 ± 0.379	6.96 ± 0.187	7.17 ± 0.162	13.41 ± 0.395	13.28±0.282	23.24±0.403	23.53±0.026

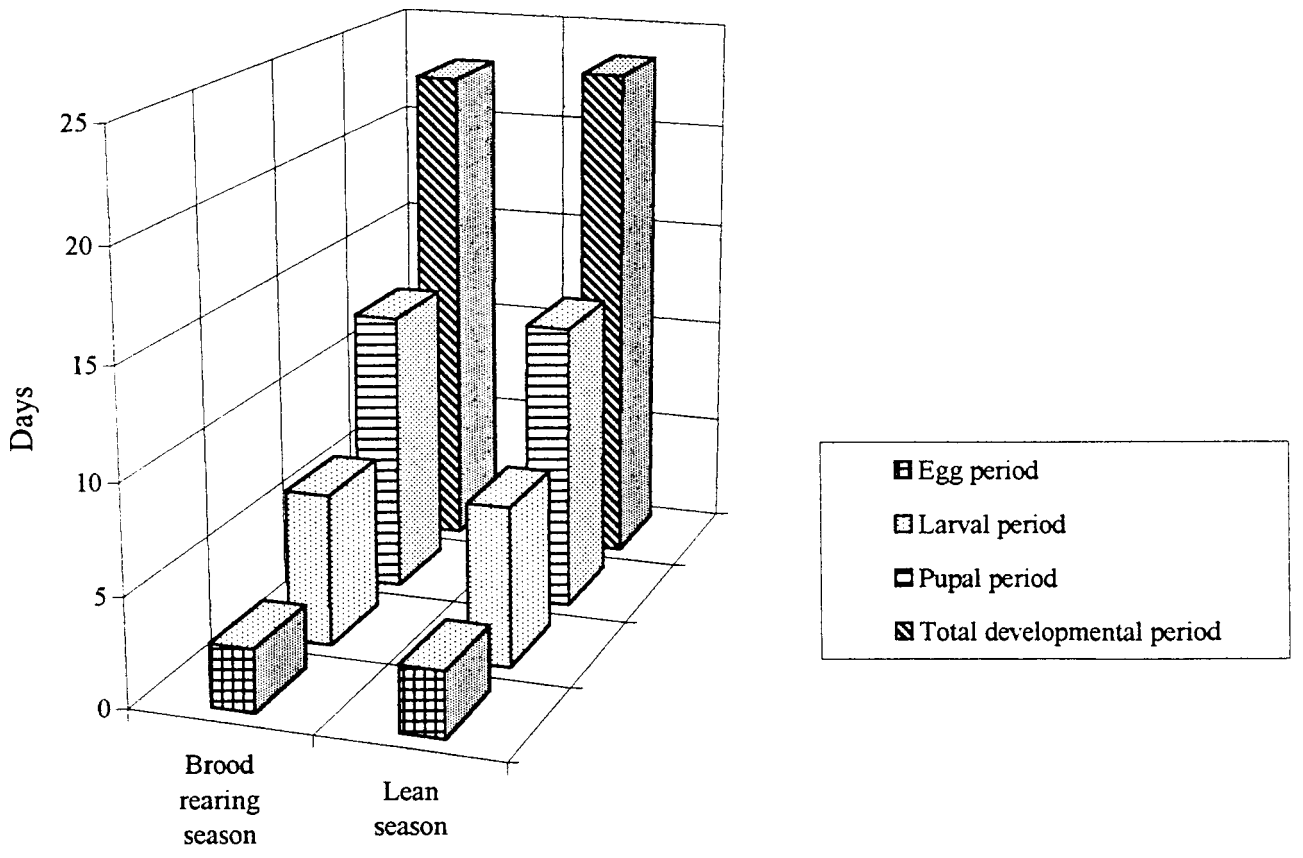

Fig 2 Duration of the developmental stages of *A. mellifera* drones in different seasons

4.1.1.3 **Queen**

The mean duration of egg stage was 2.68 ± 0.0698 days, larval stage 4.66 ± 0.2154 days and pupal stage 7.2 ± 0.126 days (Table 3).

Table 3 **Duration (Days) of developmental stages of *A. mellifera* queen**

Colony Number	Brood rearing season			
	Egg stage	Larval stage	Pupal stage	Total developmental period
1	2.6	4.4	7.4	14.4
2	2.6	4.6	7.0	14.2
3	2.8	4.8	7.2	14.8
4	2.8	5.0	7.2	15.0
5	2.6	4.5	7.2	14.3
Mean ± SD	2.68 ± 0.069	4.66 ± 0.2154	7.2 ± 0.126	14.54 ± 0.3072

The total period of development took 14.54 ± 0.307 days during brood rearing season, the only season in which successful dequeening of colonies is possible in Kerala.

4.1.2 ***Apis cerana indica***

4.1.2.1 **Workers**

The mean duration of the egg stage of worker bees varied from 2.92 ± 0.039 days in lean season to 2.96 ± 0.069 days during honey flow season (Table 4). During brood rearing season it was 2.94 ± 0.089 days. Larval period was 5.86 ± 0.098 days in lean season and 5.91 ± 0.097 days in honey flow season. The pupal period also did not vary much between different seasons. It was 10.2 ± 0.208 in brood rearing season, 10.17 ± 0.063 days in lean season and 10.18 ± 0.236 days in honey flow season. Thus the total development from egg to adult took 18.89 ± 0.15 days in honey flow season,

Table 4 **Duration (in days) of the developmental stages of *Apis cerana indica* workers**

Colony No.	Egg stage			Larval stage (upto capping of cells)			Pupal stage			Total developmental period		
	Brood rearing season	Honey flow season	Lean season	Brood rearing season	Honey flow season	Lean season	Brood rearing season	Honey flow season	Lean season	Brood rearing season	Honey flow season	Lean season
1	3.07	3.05	2.96	5.70	5.77	5.70	9.80	9.95	10.25	18.52	18.92	18.77
2	2.90	3.02	2.95	5.47	5.92	5.87	10.20	16.17	10.23	18.60	19.05	19.38
3	2.96	2.92	2.93	5.77	6.07	5.83	10.28	10.22	10.17	19.62	18.63	19.20
4	2.98	2.86	2.88	5.75	5.87	6.00	10.40	10.60	10.13	19.14	19.02	19.35
5	2.80	2.93	2.86	6.02	5.90	5.90	10.30	9.96	10.08	19.12	18.83	18.83
Mean ± SD	2.94 ± 0.089	2.96 ± 0.069	2.92 ± 0.039	5.74 ± 0.175	5.91 ± 0.097	5.86 ± 0.098	10.20 ± 0.208	10.18 ± 0.236	10.17 ± 0.063	19.00 ± 0.402	18.89 ± 0.15	19.11 ± 0.0258

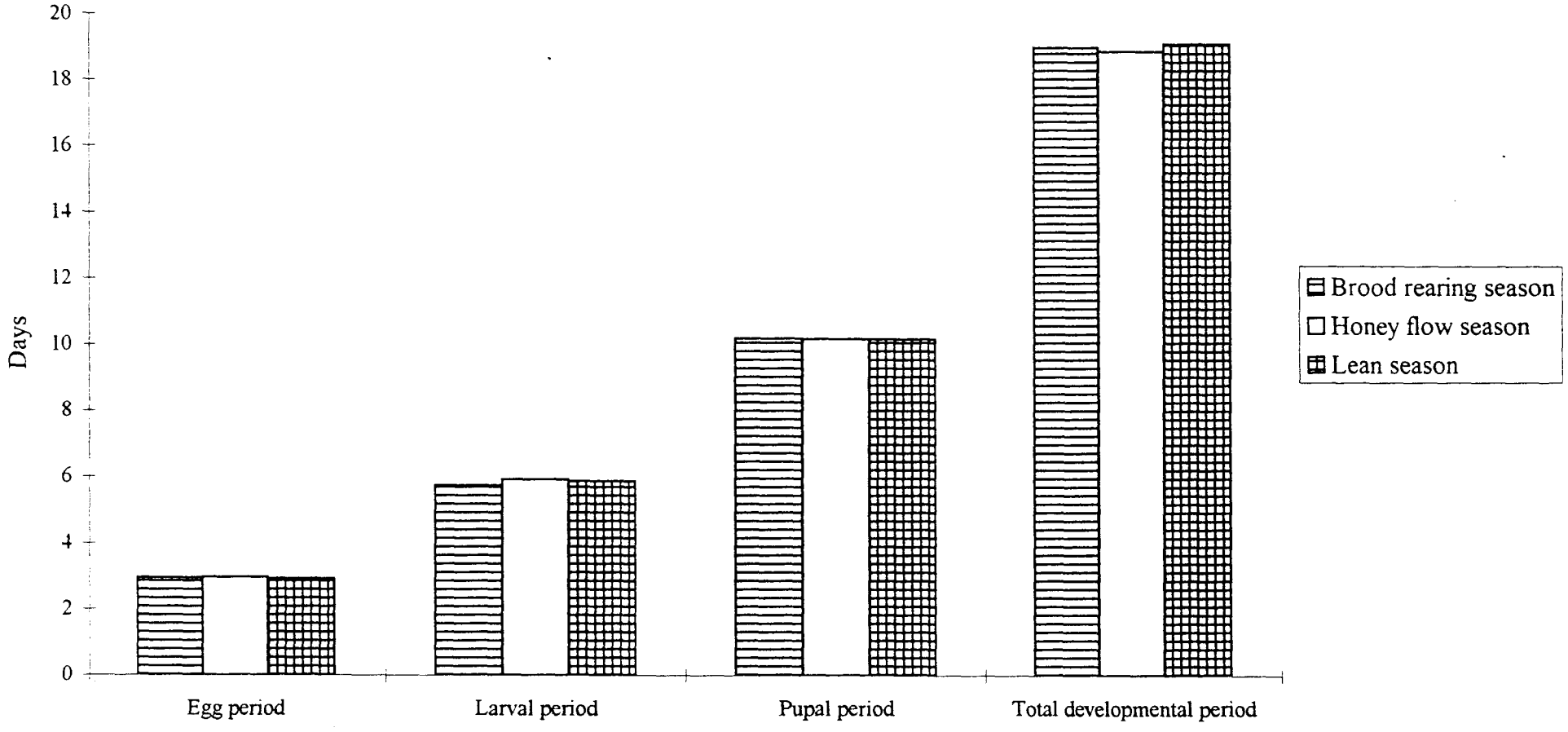

Fig 3 Duration of the developmental stages of *A. cerana indica* workers in different seasons

19.00 ± 0.402 days in brood rearing season and 19.11 ± 0.0258 days in lean season. The influence of seasons on the duration of different developmental stages were not significant.

4.1.2.2 **Drones**

The data on the durations of developmental stages of drones are presented in Table 5 and illustrated in Fig. 4. The mean egg period was 2.85 ± 0.084 days in brood rearing season and 2.99 ± 0.075 days during lean season. Larval period lasted for 6.95 ± 0.146 days in brood rearing season and 7.09 ± 0.149 days during lean season. Pupal period was completed in 12.992 ± 0.246 days during brood rearing season and 13.234 ± 0.123 days in lean season. Thus the whole period of development took 22.77 ± 0.222 days in brood rearing season and 23.342 ± 0.3082 days during lean season.

4.1.2.3 **Queen**

The total developmental period of queen bees (Table 6) took 14.74 ± 0.564 days in lean season and 14.76 ± 0.196 days in brood rearing season. The egg, larval and pupal periods during brood rearing season and lean season were 2.8 ± 0.1789 days, 4.84 ± 0.2332 days 7.12 ± 0.271 days and 2.6 ± 0.219 days, 4.68 ± 0.3709, 7.32 ± 0.24 days respectively.

4.2 **Biometrics of *A. mellifera lingustica* and *A. cerana indica***

4.2.1 ***A. mellifera lingustica***

4.2.1.1 **Workers**

The egg size of *A. mellifera* workers remained the same through out the egg period (Table 7 ; Fig. 5). The average size of the egg was 1.5 mm in length and 0.324

Table 5 **Duration (in days) of the developmental stages of *Apis cerana indica* drones**

Colony No	Egg stage		Larval stage		Pupal stage		Total developmental period	
	Brood rearing season	Lean season	Brood rearing season	Lean season	Brood rearing season	Lean season	Brood rearing season	Lean season
1	2.95	3.05	6.75	7.15	13.00	13.28	22.70	23.49
2	2.75	3.02	6.85	7.35	12.63	13.40	22.43	23.88
3	2.95	3.00	7.00	7.05	13.40	13.03	23.05	23.08
4	2.80	2.85	6.80	6.95	13.00	13.28	22.70	23.08
5	2.80	3.05	7.15	6.95	12.93	13.18	22.98	23.18
Mean ± SD	2.85±0.084	2.99±0.075	6.95±0.146	7.09±0.149	12.99±0.245	13.23±0.124	22.77±0.222	23.34±0.308

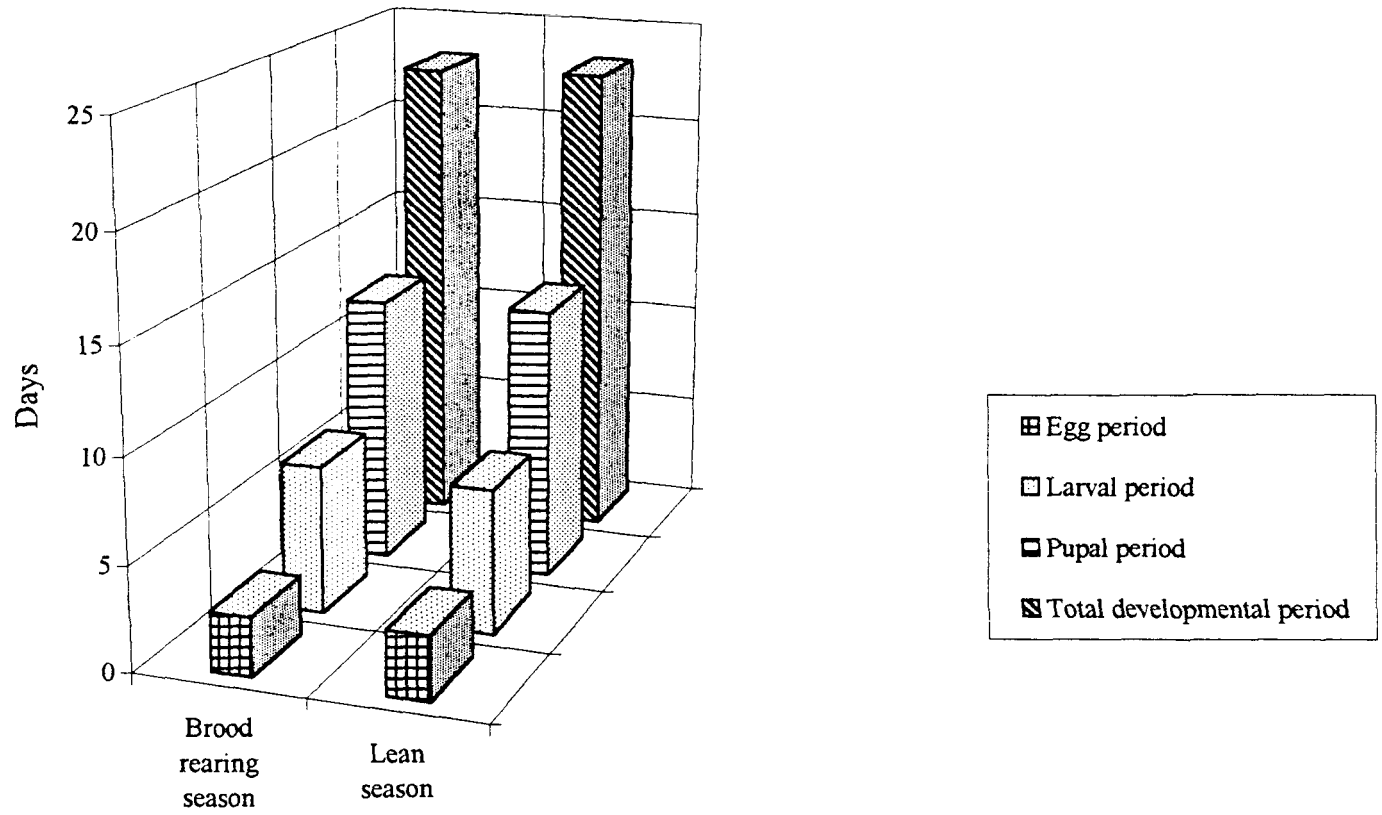

Fig 4 Duration of developmental stages of *A. cerana indica* drones in different seasons

Table 6 **Duration (in days) of the developmental stages of *Apis cerana indica* queen**

Colony No	Egg stage		Larval stage		Pupal stage		Total developmental period	
	Brood rearing season	Lean season	Brood rearing season	Lean season	Brood rearing season	Lean season	Brood rearing season	Lean season
1	2.60	2.60	4.60	4.40	7.20	7.20	14.40	14.20
2	2.60	2.60	4.60	5.40	7.60	7.00	14.80	15.70
3	2.80	3.00	5.00	4.40	7.00	7.60	14.80	15.00
4	3.00	2.40	5.20	4.60	6.80	7.20	15.00	14.20
5	3.00	2.40	4.80	4.60	7.00	7.60	14.80	14.60
Mean ± SD	2.80±0.179	2.60±0.219	4.84±0.233	4.68±0.371	7.12±0.271	7.32±0.24	14.76±0.196	14.74±0.564

Table 7 **Biometric observations on *Apis mellifera* workers (mm)**

Sample No	Egg (length x breadth)			Larvae (length x breadth)				
	1st day	2nd day	3rd day	1st day	2nd day	3rd day	4th day	5th day
1	1.52 x 0.35	1.50 x 0.34	1.49 x 0.34	2.00 x 0.60	4.80 x 1.15	6.80 x 2.27	10.4 x 3.50	13.20 x 4.95
2	1.53 x 0.34	1.52 x 0.35	1.50 x 0.35	1.95 x 0.60	4.90 x 1.15	7.10 x 2.10	10.56 x 3.70	13.70 x 4.90
3	1.50 x 0.35	1.50 x 0.34	1.55 x 0.34	2.04 x 0.59	4.92 x 1.11	8.25 x 2.66	10.75 x 3.95	13.90 x 4.92
4	1.50 x 0.34	1.52 x 0.35	1.50 x 0.34	1.99 x 0.58	4.74 x 1.47	7.64 x 2.36	10.90 x 3.65	14.40 x 5.70
5	1.50 x 0.34	1.49 x 0.36	1.51 x 0.35	2.23 x 0.59	4.01 x 1.34	8.40 x 2.67	10.30 x 3.41	13.50 x 4.60
Mean ± SD	1.51 ± 0.013 x 0.324 ± 0.042	1.51 ± 0.013 x 0.348 ± 0.007	1.51 ± 0.02 x 0.344 ± 0.005	2.06 ± 0.137 x 0.592 ± 0.007	4.67 ± 0.34 x 1.244 ± 0.138	7.63 ± 0.624 x 2.412 ± 0.222	10.58 ± 0.22 x 3.64 ± 0.185	13.74 ± 0.40 x 5.014 ± 0.365

(contd.)

Sample No	Pupae (length x breadth)				
	1st day	3rd day	5th day	7th day	9th day
1	14.25 x 5.23	12.51 x 6.25	13.13 x 5.25	14.24 x 5.25	14.45 x 5.25
2	14.32 x 6.12	13.36 x 5.27	14.75 x 5.50	14.67 x 6.03	14.76 x 5.12
3	13.52 x 5.12	14.31 x 4.75	14.31 x 6.12	14.42 x 5.72	15.12 x 5.2
4	14.10 x 7.21	14.71 x 5.54	15.15 x 6.25	14.05 x 6.01	14.17 x 5.76
5	15.25 x 5.21	14.52 x 5.02	13.75 x 5.95	14.51 x 5.73	14.52 x 5.23
Mean ± SD	14.28 ± 0.557 x 5.78 ± 0.802	13.88 ± 0.83 x 5.37 ± 0.514	14.18 ± 0.746 x 5.814 ± 0.379	14.378 ± 0.215 x 5.748 ± 0.280	14.60 ± 0.319 x 5.312 ± 0.228

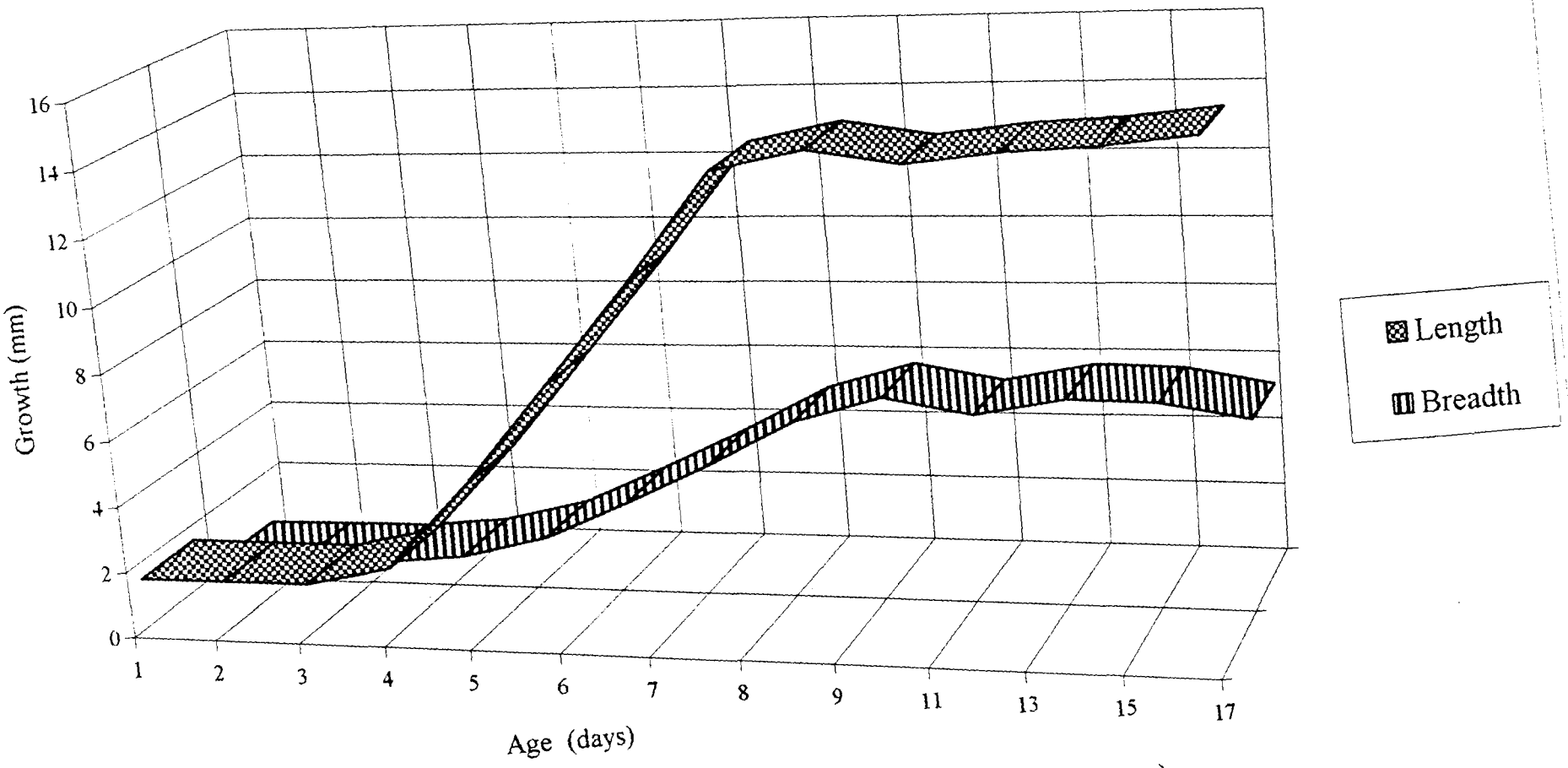

Fig. 5 Growth of *Apis mellifera* workers with age (from egg to pupa)

mm in breadth. The length and breadth of larvae increased substantially from hatching onwards. The sizes (length x breadth) of 1, 2, 3, 4 and 5 days old larvae were 2.06 x 0.59, 4.67 x 1.22, 7.63 x 2.41, 10.58 x 3.64 and 13.75 x 5.01 mm respectively. The size increase continued upto the first day of the pupal stage (14.28 x 5.78 mm). There after the size remained more or less the same with little change.

4.2.1.2 **Drones**

The average size of eggs of drones was 1.52 x 0.348 mm (Table 8). The size of the larva increased from 3.4 x 0.83 mm in the very first day of hatching to 16.68 x 7.21 mm in 6^{th} day. The growth continued upto first day after capping.

4.2.2 *A. cerana indica*

4.2.2.1 **Workers**

The egg size of worker bees did not show any change with age and the mean size was 1.58 x 0.38 mm (Table 9). The size (length x breadth) of 1, 2, 3, 4 and 5 days old larvae were 1.93 x 0.55 mm, 5.46 x 1.78 mm, 7.98 x 2.04 mm, 7.49 x 3.79 and 8.81 x 4.22 mm respectively. Here also the growth continued upto one day after capping.

4.2.2.2 **Drones**

The average size of eggs was 1.58 x 0.38 mm (Table 10). The size (length x breadth) of the larvae increased from 2.58 x 0.7 mm to 11.75 x 6.97 mm.

4.3 **Brood rearing activity**

4.3.1 *Apis mellifera*

The data on the egg laying performance of the five selected queens of *A. mellifera* are tabulated in Table 11 and illustrated in Fig 9. It is evident from the table

Table 9 **Biometric observations on *Apis cerana indica* workers (mm)**

Sample	Egg (length x breadth)			Larvae (length x breadth)				
No	1st day	2nd day	3rd day	1st day	2nd day	3rd day	4th day	5th day
1	1.554 x 0.383	1.548 x 0.395	1.576 x 0.408	1.940 x 0.540	5.540 x 1.960	7.900 x 2.230	7.960 x 3.800	8.760 x 4.180
2	1.556 x 0.384	1.596 x 0.389	1.568 x 0.408	1.820 x 0.540	5.300 x 1.750	8.000 x 2.480	8.240 x 3.870	8.580 x 4.200
3	1.596 x 0.392	1.584 x 0.408	1.610 x 0.389	1.980 x 0.550	5.260 x 1.850	8.140 x 2.170	7.660 x 3.650	8.950 x 4.050
4	1.652 x 0.378	1.596 x 0.389	1.598 x 0.400	1.960 x 0.550	5.500 x 1.550	7.940 x 2.500	7.940 x 3.900	8.900 x 4.440
5	1.590 x 0.381	1.590 x 0.389	1.576 x 0.372	1.940 x 0.560	5.700 x 1.800	7.940 x 2.320	7.920 x 3.750	8.860 x 4.220
Mean ±	1.58 ± 0.037 x	1.58 ± 0.017 x	1.59 ± 0.015 x	1.93 ± 0.056 x	5.46 ± 0.162 x	7.98 ± 0.084 x	7.49 ± 0.184 x	8.81 ± 0.131 x
SD	0.38 ± 0.005	0.384 ± 0.007	0.395 ± 0.013	0.55 ± 0.007	1.78 ± 0.135	2.04 ± 0.132	3.794 ± 0.890	4.22 ± 0.126

(contd.)

Sample No	Pupae (length x breadth)				
	1st day	3rd day	5th day	7th day	9th day
1	10.10 x 5.24	11.20 x 4.50	10.50 x 4.20	10.25 x 6.12	10.00 x 5.50
2	10.25 x 5.25	10.25 x 4.85	10.52 x 3.75	10.15 x 5.12	10.23 x 4.95
3	9.75 x 4.85	9.72 x 4.25	10.75 x 3.75	9.94 x 5.24	10.30 x 5.21
4	10.50 x 5.35	10.56 x 4.22	9.95 x 5.12	10.25 x 5.41	10.25 x 5.34
5	10.80 x 5.75	11.10 x 4.25	10.50 x 3.80	10.13 x 5.13	10.70 x 5.12
Mean ± SD	10.25 ± 0.356 x 5.28 ± 0.287	10.56 ± 0.548 x 4.14 ± 0.24	10.44 ± 0.264 x 4.13 ± 0.052	10.14 ± 0.113 x 5.404 ± 0.373	10.29 ± 0.226 x 5.224 ± 0.187

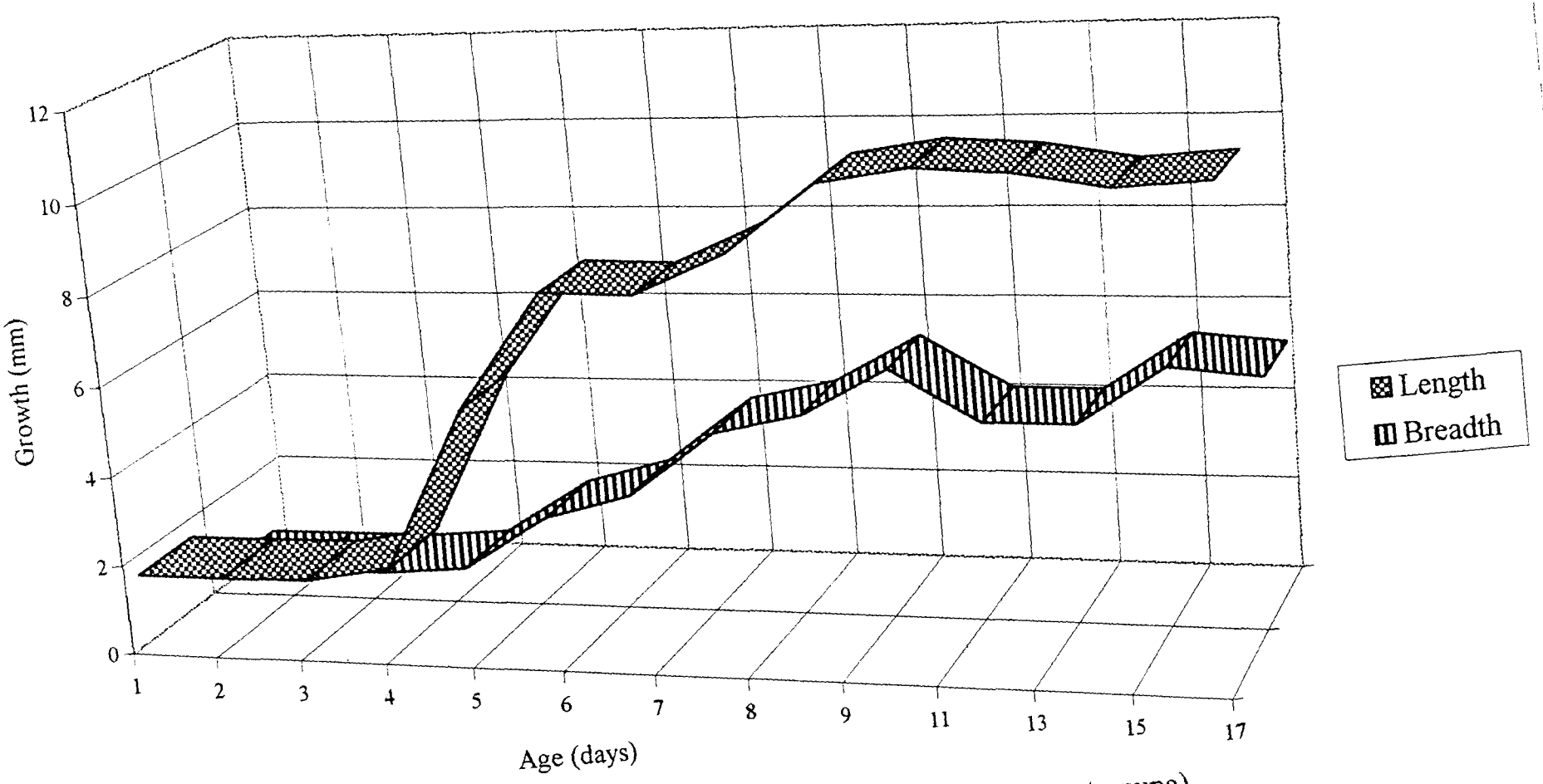

Fig. 7 Growth of *Apis cerana indica* workers with age (from egg to pupa)

Table 8 **Biometric observations on *Apis mellifera* drones (mm)**

Sample No	Mean egg size (length x breadth)	Larvae (length x breadth)					
		1st day	2nd day	3rd day	4th day	5th day	6th day
1	1.51 x 0.35	3.12 x 0.81	5.20 x 1.25	7.63 x 2.27	10.50 x 3.50	14.60 x 5.10	16.23 x 7.20
2	1.53 x 0.34	3.21 x 0.79	4.80 x 1.34	8.18 x 2.80	10.75 x 3.67	14.12 x 5.13	16.73 x 7.13
3	1.51 x 0.34	0.55 x 0.84	6.10 x 1.75	8.25 x 2.81	10.92 x 3.95	14.80 x 4.92	16.89 x 6.93
4	1.52 x 0.35	3.72 x 0.86	5.81 x 1.80	8.36 x 2.31	10.23 x 4.23	14.20 x 5.20	17.10 x 7.32
5	1.53 x 0.36	3.42 x 0.87	5.51 x 1.56	8.22 x 2.83	10.38 x 3.65	14.10 x 5.70	16.44 x 7.48
Mean ± SD	1.52 ± 0.009 x 0.348 ± 0.007	3.40 ± 0.219 x 0.83 ± 0.03	5.48 ± 0.455 x 1.54 ± 0.217	8.13 ± 0.256 x 2.60 ± 0.257	10.56 ± 0.25 x 3.80 ± 0.259	14.36 ± 0.283 x 5.21 ± 0.262	16.68 ± 0.311 x 7.21 ± 0.184

contd.

Sample	Pupae (length x breadth)				
No	1st day	3rd day	5th day	8th day	12th day
1	17.12 x 7.23	17.36 x 7.03	17.32 x 7.03	17.41 x 6.97	17.34 x 7.13
2	17.34 x 7.13	16.96 x 7.15	17.76 x 7.16	17.34 x 7.12	17.36 x 7.03
3	17.46 x 7.63	17.12 x 7.65	17.45 x 7.23	17.23 x 7.06	17.22 x 7.42
4	17.22 x 7.42	17.35 x 7.43	17.06 x 7.49	17.61 x 7.03	17.76 x 7.16
5	17.32 x 7.53	17.36 x 7.54	17.34 x 7.82	17.43 x 7.05	17.46 x 7.63
Mean ± SD	17.29 ± 0.115 x 7.38 ± 0.185	17.82 ± 1.07 x 7.36 ± 0.234	17.39 ± 0.226 x 7.32 ± 0.271	17.40 ± 0.124 x 7.05 ± 0.048	17.43 ± 0.183 x 7.28 ± 0.221

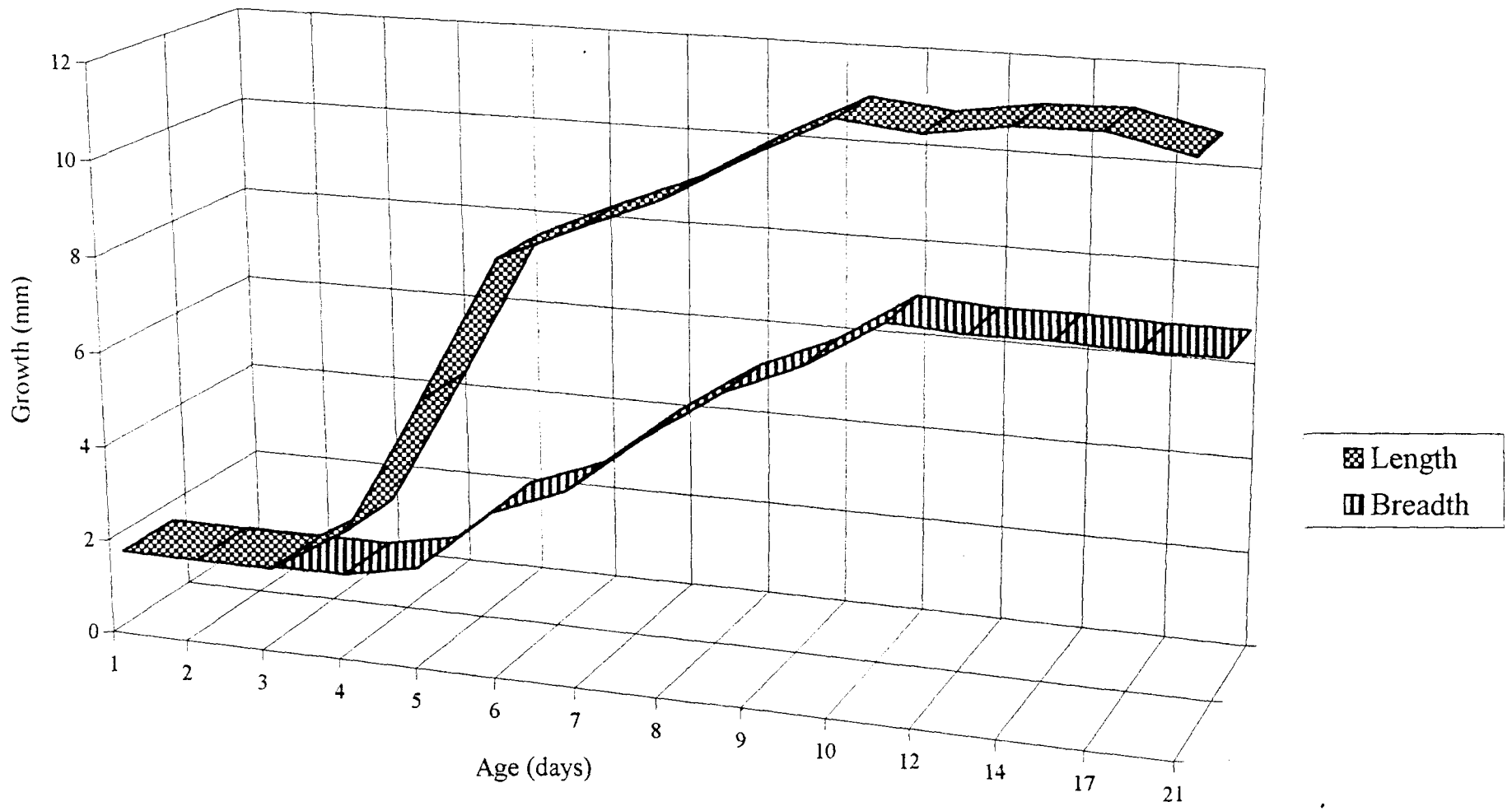

Fig. 8 Growth of *Apis cerana indica* drones with age (from egg to pupa)

Table 10 **Biometric observations on *Apis cerana indica* drones (mm)**

Sample No	Mean egg size (length x breadth)	Larvae (length x breadth)					
		1st day	2nd day	3rd day	4th day	5th day	6th day
1	1.58 x 0.39	3.41 x 0.67	5.78 x 1.98	8.21 x 2.78	9.31 x 4.10	9.92 x 5.23	10.71 x 5.22
2	1.59 x 0.38	0.67 x 0.68	5.21 x 2.10	8.32 x 2.92	9.13 x 4.08	9.98 x 5.21	10.78 x 6.13
3	1.60 x 0.38	2.81 x 0.76	4.89 x 2.21	8.62 x 2.47	9.41 x 3.98	10.10 x 5.07	11.12 x 5.83
4	1.57 x 0.38	2.32 x 0.78	5.68 x 1.96	8.73 x 2.96	9.32 x 3.92	9.78 x 5.36	10.96 x 6.23
5	1.57 x 0.37	2.73 x 0.63	5.78 x 2.28	8.67 x 2.64	9.07 x 4.27	9.87 x 5.12	10.91 x 6.20
Mean ± SD	1.58 ± 0.001 x 0.38 ± 0.006	2.58 ± 0.189 x 0.704 ± 0.056	5.47 ± 0.357 x 2.11 ± 0.125	8.51 ± 0.206 x 2.75 ± 0.181	9.25 ± 0.127 x 4.07 ± 0.120	9.93 ± 0.107 x 5.198 ± 0.099	10.90 ± 0.143 x 5.92 ± 0.378

(contd.)

Sample	Pupae (length x breadth)				
No	1st day	3rd day	5th day	8th day	12th day
1	11.52 x 6.93	11.56 x 6.79	11.76 x 6.86	11.78 x 6.91	11.52 x 6.93
2	11.78 x 6.91	11.67 x 6.92	11.98 x 6.92	11.81 x 6.76	11.67 x 6.92
3	11.96 x 7.01	11.98 x 6.93	11.74 x 6.97	11.87 x 6.78	11.21 x 6.84
4	12.20 x 6.87	11.21 x 6.84	11.95 x 6.85	11.98 x 6.87	11.81 x 6.76
5	11.31 x 6.23	11.36 x 6.84	11.81 x 6.83	11.79 x 6.79	11.21 x 6.84
Mean ± SD	11.75 ± 0.314 x 6.97 ± 0.283	11.56 ± 0.264 x 6.86 ± 0.053	11.82 ± 0.139 x 6.89 ± 0.052	11.85 ± 0.074 x 6.82 ± 0.058	11.48 ± 0.242 x 6.84 ± 0.062

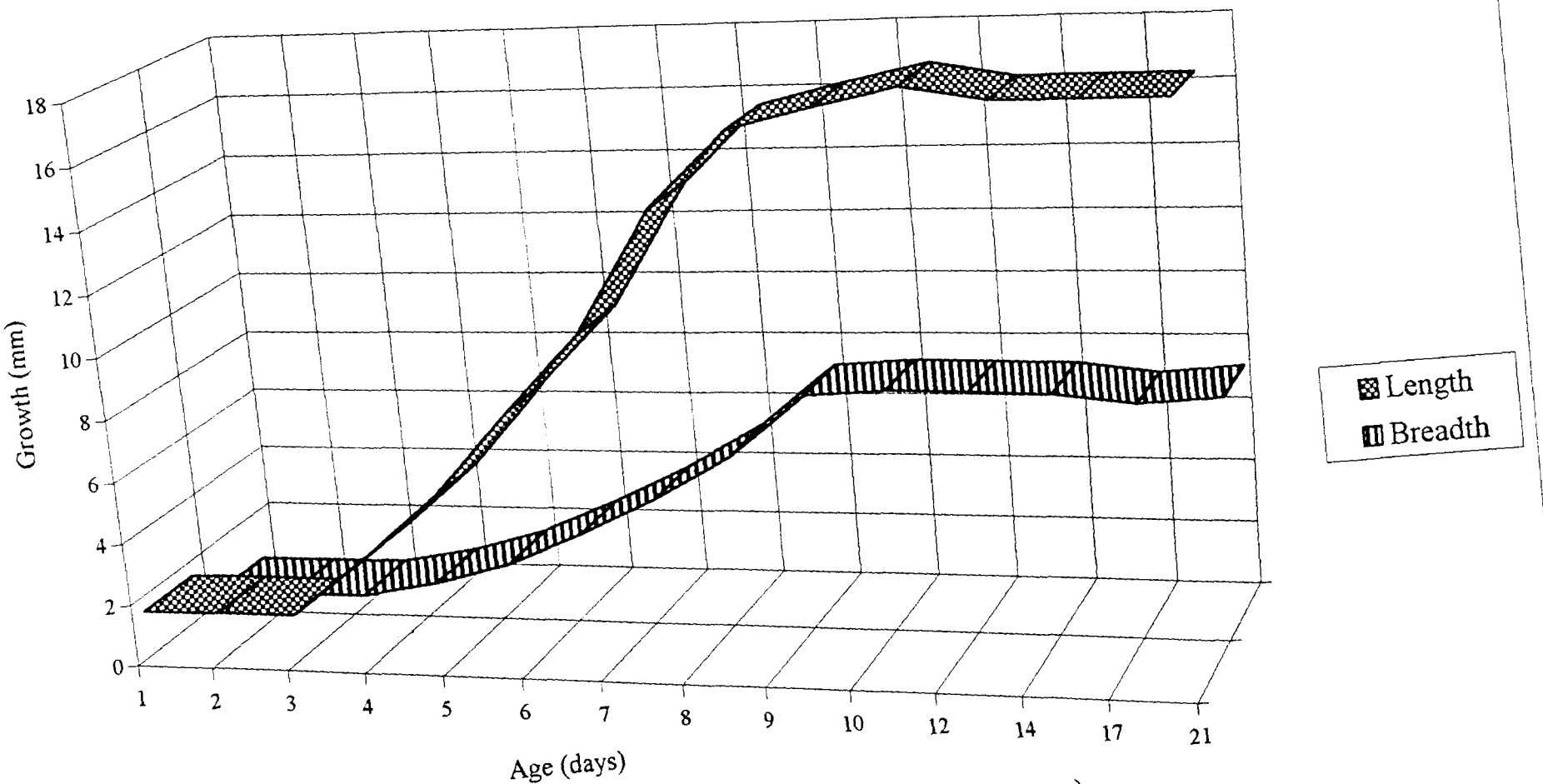

Fig. 6 Growth *Apis mellifera* drones with age (egg to pupa)

Table 11 **Egg laying performance of *Apis mellifera* Queens during 1995-96**

Date of observation	Colony 1		Colony 2		Colony 3		Colony 4		Colony 5		Mean daily average
	Total eggs laid	Daily average	Total eggs laid	Daily average	Total eggs laid	Daily average	Total eggs laid	Daily average	Total eggs laid	Daily average	
04-09-95	11041	552	11398	570	3925	206	7407	370	6939	347	409
24-09-95	9341	467	8462	423	4150	208	7410	371	6563	328	359
14-10-95	9050	453	7367	368	4396	220	4606	225	5495	275	308
03-11-95	8918	446	6594	330	3281	165	3642	182	5432	272	279
23-11-95	6704	355	3912	196	3580	179	3752	188	5854	239	231
13-12-95	427	221	3690	185	3162	158	2763	138	2185	109	162
02-01-96	4752	238	6441	332	2795	140	3344	167	2255	113	198
22-01-96	5388	269	8792	440	3297	165	4760	238	3219	161	255
13-02-96	6955	348	9649	482	5888	294	6359	318	2905	145	317
02-03-96	10591	530	16586	821	7426	371	7731	387	4666	203	465
24-03-96	4930	247	13989	699	10723	536	17424	871	10183	509	572
14-04-96	13367	668	16023	801	12915	646	15814	791	13402	670	715
05-05-96	14736	737	11988	599	11511	576	6362	318	13678	684	583
25-05-96	13725	686	8729	436	11436	572	8349	418	10580	529	528
14-06-96	9937	497	15606	780	10959	548	8729	437	10833	542	561
05-07-96	15308	765	13408	670	16363	818	15606	796	10959	548	718
25-07-96	12450	622	11560	578	14421	711	14538	727	10550	528	633
14-08-96	11827	591	10236	512	9275	464	11376	569	8379	419	511
Full one year	173447		184430		139503		149872		133677		

Average annual performance : 156186

Mean ± SD : 434 ± 172

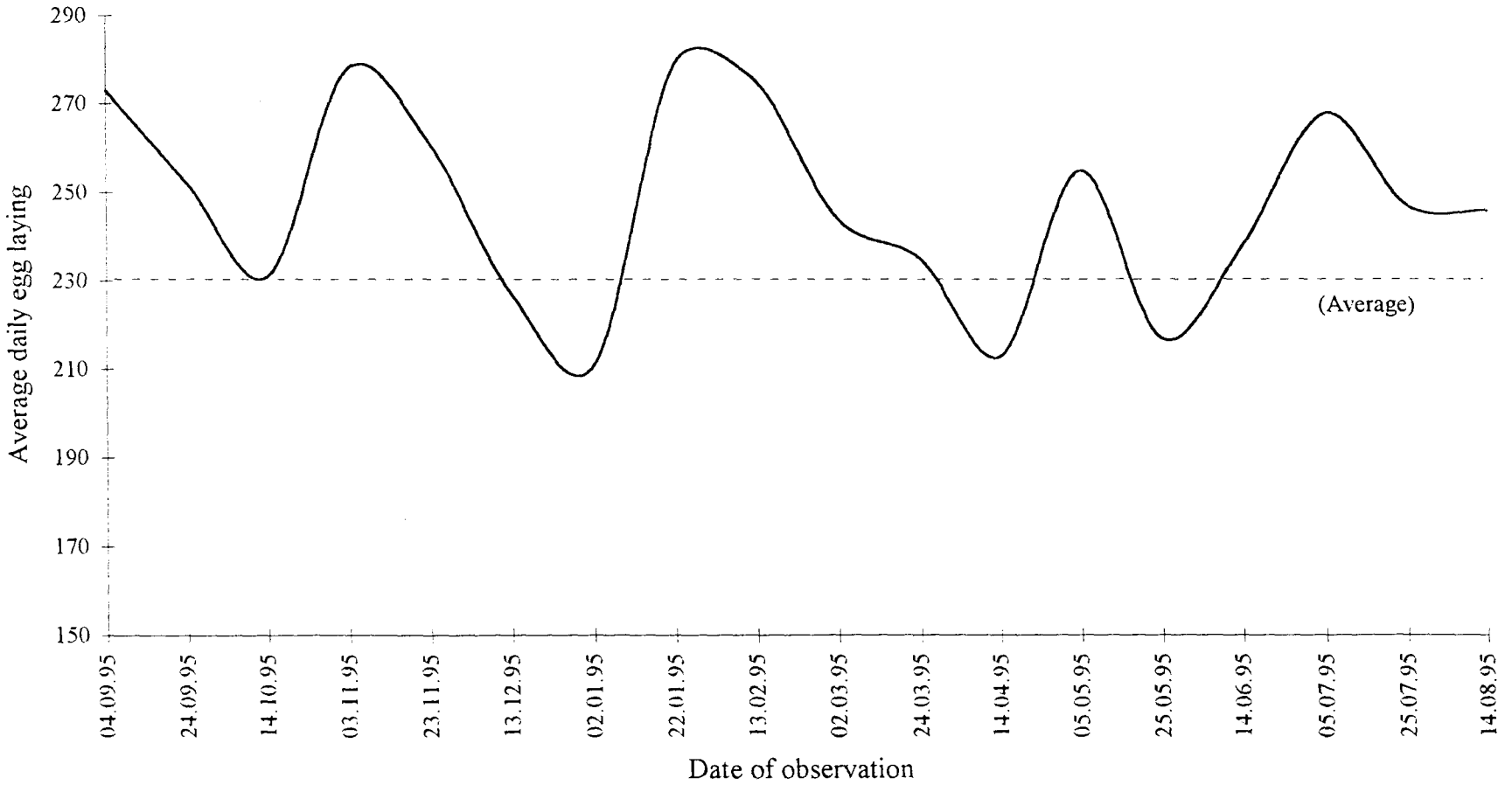

Fig. 10 Egg laying performance of *A. cerana indica* queens during 1995-1996

that the egg laying rate decreased continuously from September towards the middle of December. There after it showed a slow upward trend from January through February. From March onwards the rate of egg laying showed a conspicuous increase reaching the maximum in July (718 eggs per day). During August also the egg laying was high. Minimum egg laying was observed in the month of December (162 eggs per day). The annual performance of the queen was 1 56 186 eggs with a range from 1 33 677 to 1 84 430 eggs.

4.3.2 *Apis cerana indica*

The data on the brood rearing activity of *Apis cerana indica* are presented in the Table 12 and illustrated in Fig 10. There was no wide disparity in the egg laying rate during different the months. The daily average egg laying was 247 eggs. But laying was below average during April and May. Egg laying rate was more during September and November. Total eggs laid in an year ranged from 83 807 to 98,792 with an average of 88 086 eggs.

4.4 **Longevity**

4.4.1 *Apis mellifera*

4.4.1.1 **Workers**

Worker bees born on April 10 showed an average life span of 28.22 ± 1.603 days with a range of 25.93 to 29.82 days (Table 13, 14). More than 50 percent of the bees perished before attaining an age of 24 days. The maximum life span ranged from 51 days to 54 days (Table 13). Bees born on June 15 lived on an average for 30.97 ± 1.52 days (Table 15). The maximum life of bees ranged from 51 to 55 days. Maximum mortality was observed between 18th day and 29th day after emergence.

Table 12 **Egg laying performance of *Apis cerana indica* during 1995-96**

Date of observation	Colony 1		Colony 2		Colony 3		Colony 4		Mean Daily average
	Total eggs laid	Daily average	Total eggs laid	Daily average	Total eggs laid	Daily average	Total eggs laid	Daily average	
04-09-95	4196	210	6984	349	5181	279	3570	179	273
24-09-95	5025	251	4974	249	5115	256	5060	253	252
14-10-95	4776	239	5073	254	4578	229	4029	201	231
03-11-95	5278	264	6576	328	5873	294	4536	227	278
23-11-95	5393	270	5723	286	5355	268	4371	218	261
13-12-95	4329	216	4941	247	4314	216	4592	230	227
02-01-96	3795	190	4982	249	4333	217	3745	187	211
22-01-96	4616	231	6307	315	5515	276	5899	295	279
13-02-96	5223	261	6785	339	5964	248	5016	251	275
02-03-96	3839	192	6448	322	3768	188	5516	275	244
24-03-96	4263	213	5139	287	4176	209	5205	260	235
14-04-96	4687	234	3674	184	3603	180	5054	253	213
05-05-96	4828	241	5096	255	4851	243	5616	281	255
25-05-96	4178	209	4932	247	3867	193	4333	217	217
14-06-96	4639	232	5999	265	4366	218	QL	QL	238
05-07-96	5252	263	5723	286	5115	256	QL	QL	268
25-07-96	5115	256	5116	256	4578	229	QL	QL	247
14-08-96	4335	237	5026	251	4985	249	QL	QL	246
Full one year	83807		98792		84537				

Average annual performance : 88086

QL : Queen lost

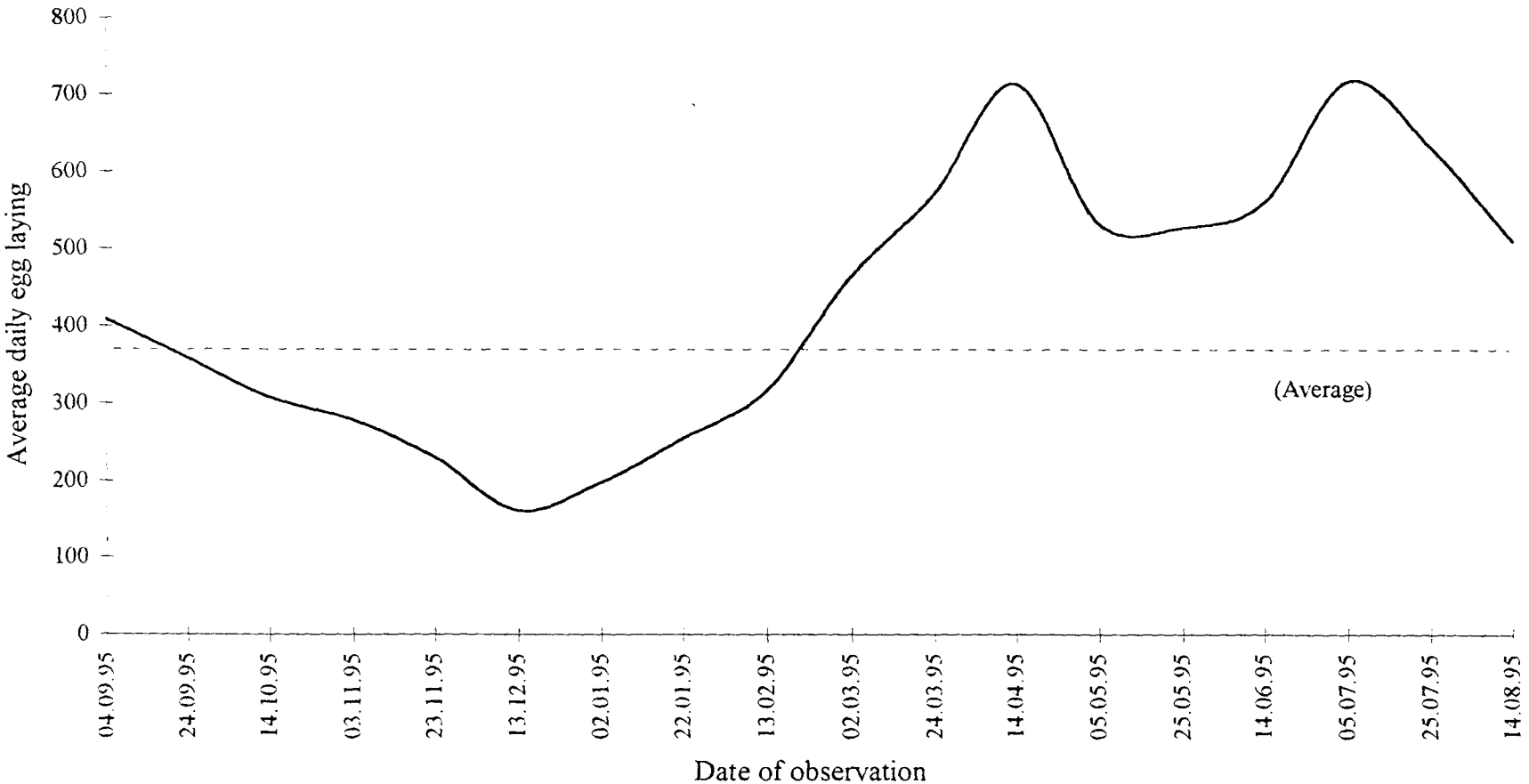

Fig. 9 Egg laying performance of *A. mellifera* queens during 1995-1996

Table 13 **Percentage of survival of *Apis mellifera* workers born on April 10, 1996**

Age in days	Colony number								Mean percentage of survival
	1		2		3		4		
	No. of bees alive	No of bees dead	No. of bees alive	No of bees dead	No. of bees alive	No of bees dead	No. of bees alive	No of bees dead	
1	100	0	100	0	100	0	100	0	100
7	86	14	89	11	93	7	96	4	91.00
14	81	5	82	7	87	6	89	7	84.75
18	75	6	74	8	67	20	71	18	71.75
21	55	20	52	22	61	5	62	9	57.50
24	47	8	45	7	53	8	51	9	49.00
27	41	6	38	7	44	9	41	10	41.00
29	35	6	31	7	41	3	39	2	36.50
31	34	1	29	2	38	3	37	2	34.75
33	29	5	27	2	33	5	35	2	31.00
35	24	5	25	2	31	2	33	2	28.25
37	23	1	21	4	29	2	31	2	26.00
39	19	4	19	2	24	4	29	2	22.75
41	13	6	18	1	21	3	26	3	19.50
43	8	5	13	5	19	2	21	5	15.25
45	7	1	11	4	18	1	19	3	13.75
47	6	1	7	4	13	5	18	1	11.00
49	3	3	5	2	7	6	15	3	7.50
50	2	1	3	2	4	3	13	2	5.50
51	1	1	2	1	3	1	7	6	3.25
52	0	1	1	1	3	0	5	2	2.25
53	0	0	1	0	2	1	1	4	1.00
54	0	0	0	1	1	1	0	1	0.25
55	0	0	0	0	0	1	0	0	0.10
56	0	0	0	0	0	0	0	0	0.00

Table 14 **Percentage of survival of *Apis mellifera* workers born on June 15, 1996**

Age in days	Colony number								Mean percentage of survival
	1		2		3		4		
	No. of bees alive	No of bees dead	No. of bees alive	No of bees dead	No. of bees alive	No of bees dead	No. of bees alive	No of bees dead	
1	100	0	100	0	100	0	100	0	100
7	91	9	90	10	93	7	92	8	91.50
14	89	2	87	3	87	5	89	3	88.00
18	82	7	75	12	81	6	82	7	80.00
21	75	7	71	4	79	2	71	11	74.00
24	69	6	67	4	71	8	69	2	69.00
27	63	6	63	4	67	4	63	6	64.00
29	55	8	51	2	61	6	57	6	56.00
31	51	4	48	3	56	5	43	14	49.50
33	47	4	44	4	51	5	41	2	45.75
35	44	3	39	5	45	6	39	2	41.75
37	43	1	37	2	41	4	37	2	39.50
39	41	2	33	4	39	2	31	6	36.00
41	39	2	31	2	32	7	28	3	32.50
43	37	2	29	2	21	11	27	1	28.50
45	27	10	24	5	14	7	25	2	22.50
47	25	2	19	5	11	3	21	4	19.00
49	21	4	17	2	7	4	19	2	16.00
50	17	14	13	4	5	2	13	6	12.00
51	11	6	9	4	2	3	7	6	6.75
52	7	4	7	2	0	2	5	2	4.75
53	5	2	5	2	0	0	1	4	2.75
54	1	4	2	3	0	0	0	1	0.75
55	0	1	1	1	0	0	0	0	0.25
56	0	0	0	1	0	0	0	0	0.00

Table 15 **Mean longevity of *A. mellifera* workers during pre-monsoon and monsoon periods**

Colony number	Mean longevity of bees born on April 10 (days)	Mean longevity of bees born on June 15 (days)
1	25.93	29.77
2	27.50	29.17
3	29.62	32.59
4	29.82	32.35
Mean ± SD	28.22 ± 1.603	30.97 ± 1.52

4.4.2 ***Apis cerana indica***

4.4.2.1 **Workers**

Data related to the longevity of *Apis cerana indica* workers are presented in Table 16 and 17. The mean longevity of April 11 born bees (Table 18) was 33.46 ± 3.575 days with a range of 28.86 days to 37.67 days. The maximum age of bees ranged from 49 to 55 days (Table 16). More than 50 per cent of the bees got killed before attaining an age of 37 days. Mortality rate was more from 29th day to 35th day.

The longevity of bees (Table 18) born on June 16 ranged from 29.42 days to 36.4 days with a mean of 33.32 ± 2.54 days. More than 50 per cent of bees died before 35th day.

Table 16 **Percentage of survival of *Apis cerana indica* workers born on April 11, 1996.**

Age in days	Colony number								Mean percentage of survival
	1		2		3		4		
	No. of bees alive	No of bees dead	No. of bees alive	No of bees dead	No. of bees alive	No of bees dead	No. of bees alive	No of bees dead	
1	100	0	100	0	100	0	100	0	100.00
7	93	7	97	3	93	7	91	9	93.50
14	91	2	93	4	90	3	87	4	90.25
18	86	5	92	1	85	5	81	6	86.00
21	82	4	90	2	81	4	79	2	83.00
24	81	1	89	1	79	2	77	2	81.50
27	76	5	81	8	77	2	76	1	77.50
29	64	2	79	2	68	9	74	2	70.25
31	60	4	77	2	65	3	65	9	66.75
33	55	5	71	6	64	1	51	4	60.25
35	48	7	62	9	60	4	43	8	53.25
37	39	9	52	10	51	9	33	10	43.75
39	34	5	49	3	48	3	24	9	38.75
41	24	10	45	4	41	7	21	3	32.75
43	20	4	37	8	37	4	17	3	27.75
45	18	2	28	9	32	5	13	4	22.75
47	17	1	23	5	22	10	11	2	18.25
49	13	4	17	6	13	9	7	4	14.25
50	9	4	15	2	11	2	0	7	8.75
51	7	2	9	6	4	7	0	0	5.00
52	5	2	5	4	3	1	0	0	3.25
53	4	1	4	1	1	2	0	0	2.25
54	0	4	2	2	0	1	0	0	0.50
55	0	0	1	1	0	0	0	0	0.25
56	0	0	0	1	0	0	0	0	0.00

Table 17 **Percentage of survival of *Apis cerana indica* workers born on June 16, 1996**

Age in days	Colony number								Mean percentage of survival
	1		2		3		4		
	No. of bees alive	No of bees dead	No. of bees alive	No of bees dead	No. of bees alive	No of bees dead	No. of bees alive	No of bees dead	
1	100	0	100	0	100	0	100	0	100.00
7	94	6	97	3	90	10	89	11	91.75
14	93	1	90	7	88	2	88	1	89.75
18	90	3	86	4	80	8	87	1	85.75
21	85	5	84	2	79	1	80	7	84.50
24	81	4	75	9	70	9	73	7	74.75
27	80	1	67	8	65	5	70	3	70.50
29	75	5	60	7	64	1	58	12	64.25
31	65	10	57	3	60	4	51	7	58.25
33	60	5	51	6	52	8	50	1	53.25
35	55	5	44	7	39	3	43	1	45.25
37	47	8	41	3	38	1	41	2	41.75
39	38	9	30	11	29	9	38	4	33.75
41	31	7	23	7	21	8	30	8	26.25
43	25	6	19	4	18	3	25	5	21.75
45	20	5	16	3	17	1	21	4	18.50
47	15	5	15	1	12	4	18	3	15.00
49	14	1	14	1	4	8	17	1	12.25
50	8	6	13	3	1	3	14	3	8.50
51	5	3	7	4	0	1	9	3	5.25
52	1	4	1	6	0	0	7	5	2.25
53	0	1	1	0	0	0	5	4	1.50
54	0	0	0	1	0	0	2	3	0.50
55	0	0	0	0	0	0	0	2	0.00
56	0	0	0	0	0	0	0	0	0.00

Table 18 **Mean longevity of *A. cerana indica* workers during pre-monsoon and monsoon periods**

Colony number	Mean longevity of bees born on April 11 (days)	Mean longevity of bees born on June 16 (days)
1	31.20	36.40
2	37.67	33.07
3	36.13	29.42
4	28.86	34.39
Mean ± SD	33.46 ± 3.575	33.32 ± 2.545

4.4.2.2 **Drones**

Results presented in Table 20 shows that the longevity of drones ranged from 30.35 to 36.3 days with an average life span of 34.58 ± 2.454 days. The maximum life span ranged from 57 to 60 days much more than that of worker bees. More than 50 per cent of the bees died before attaining an age of 37 days (Table 19). It is evident from these studies that in Kerala the longevity of drones is little longer than that of worker bees.

Table 20 **Mean longevity of *A. cerana indica* drones during pre-monsoon season**

Colony number	Mean longevity of bees born on April 11 (days)
1	36.3
2	36.04
3	35.63
4	30.35
Mean ± SD	34.58 ± 2.454

Table 19 **Percentage of survival of *Apis cerana indica* drones born on April 11, 1996**

Age in days	Colony number								Mean percentage of survival
	1		2		3		4		
	No. of bees alive	No of bees dead	No. of bees alive	No of bees dead	No. of bees alive	No of bees dead	No. of bees alive	No of bees dead	
1	100	0	100	0	100	0	100	0	100.00
7	97	3	94	6	93	7	91	9	93.75
14	91	6	90	4	91	2	89	2	90.25
18	88	3	87	3	84	7	83	6	85.50
21	86	2	86	1	81	3	80	3	83.25
24	84	5	81	5	79	2	74	6	78.75
27	75	6	72	9	71	8	69	5	71.75
29	68	7	64	8	68	3	55	4	63.75
31	64	4	61	3	61	7	53	2	59.75
33	60	4	55	6	54	7	51	2	55.00
35	59	1	51	4	51	3	45	6	51.50
37	49	10	44	7	43	8	39	6	43.75
39	41	8	41	3	37	6	36	3	38.75
41	36	5	33	9	34	3	31	5	33.50
43	31	5	30	3	27	7	24	7	28.00
45	29	2	29	1	26	1	21	3	26.25
47	27	5	28	1	24	2	18	3	23.50
49	21	3	27	1	23	1	17	1	22.00
50	18	3	26	1	19	4	14	3	19.25
51	16	2	23	3	16	3	7	7	15.50
52	9	7	21	2	13	3	6	1	12.25
53	4	5	19	2	8	5	5	1	9.00
54	3	1	13	6	4	4	4	1	6.00
55	2	1	11	2	2	2	2	2	4.25
56	1	1	8	3	0	2	1	1	2.50
57	0	1	6	2	0	0	1	0	1.75
58	0	0	3	3	0	0	0	1	0.75
59	0	0	1	2	0	0	0	0	0.25
60	0	0	0	1	0	0	0	0	0.00

4.5 **Natural enemies**

The aim was only to record the incidence of natural enemies and diseases in *A. cerana indica* and *A. mellifera* colonies under Kerala conditions. Hence only cursory observations were done and the major findings of the study are furnished below.

4.5.1 **Hornets**

Among the different species of Hornets incidence of only *Vespa orientalis* was noticed. The number of Hornets observed near the entrances at different intervals from 6 am to 6 pm are presented in Table 21. It will be seen that hornet attack was noticed only from May to December and their attack was more during May to August. Further the hornets appeared mostly in the morning between 7 am and 10 am and practically very few in the afternoon. In *A. cerana* colonies also incidence followed a similar pattern as that in *A. mellifera* (Table. 22). In both the species there was no hornet attack during the months of January to April (honey flow season) except for stray individuals.

4.5.2 **Wax moths**

Neither presence of wax moths nor damage to combs was observed in *A. mellifera* colonies. However some larvae were noticed below the paper sheet kept for observation (Table 23). These larvae were more during brood rearing season.

In *A. cerana indica* colonies wax moth incidence was noticed through out the year except during the months of May, June and December (Table 24).

4.5.3 **Death head moth (*Acherontia styx*, Sphingidae)**

During September to December these moths were seen at times inside the hives of *A. mellifera*. The larval stage of this enemy is spent on crops like groundnut and

Table No 21 **Number of hornests visiting *Apis mellifera* colonies at different intervals of the day**

Month	Time of observation													Total
	6 am	7 am	8 am	9 am	10 am	11 am	12 noon	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm	
Sept. 1995	-	-	1	1	-	-	-	-	-	-	1	-	-	2
Oct. 1995	-	-	1	2	1	-	-	-	-	-	-	-	-	4
Nov. 1995	-	-	2	4	-	-	-	-	-	-	-	-	-	6
Dec. 1995	-	-	2	1	1	-	-	-	-	-	-	-	-	3
Jan. 1996	-	1	-	-	-	-	-	-	-	-	-	-	-	1
Feb. 1996	-	-	-	-	-	-	-	-	-	1	-	-	-	1
Mar. 1996	-	-	-	-	-	-	-	-	-	-	-	-	-	-
April 1996	-	-	-	-	-	-	-	-	-	-	-	-	-	-
May 1996	-	1	2	3	1	-	-	-	-	-	-	-	-	7
June 1996	-	2	3	3	1	-	-	-	-	-	-	-	-	9
July 1996	-	1	2	4	1	-	-	-	1	2	-	-	-	11
Aug. 1996	-	2	1	2	3	-	-	-	-	1	-	-	-	9

Table 22 **Number of hornests visiting *Apis cerana indica* colonies at different intervals of the day**

Month	Time of observation													Total
	6 am	7 am	8 am	9 am	10 am	11 am	12 noon	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm	
Sept. 1995	-	-	2	2	1	-	-	-	-	-	-	-	-	5
Oct. 1995	-	-	-	3	2	1	-	-	-	-	-	-	-	6
Nov. 1995	-	-	1	1	3	-	-	-	-	-	-	-	-	5
Dec. 1995	-	-	-	2	-	-	1	-	-	-	1	-	-	3
Jan. 1996	-	-	1	1	-	-	-	-	-	-	-	-	-	4
Feb. 1996	-	-	-	-	1	-	-	-	-	-	-	-	-	1
Mar. 1996	-	-	-	-	-	-	-	-	-	-	-	-	-	-
April 1996	-	-	-	-	-	-	-	-	-	-	-	-	-	-
May 1996	-	1	2	4	1	-	-	-	-	-	1	-	-	9
June 1996	-	1	3	2	-	-	-	-	-	1	-	-	-	7
July 1996	-	-	2	3	-	-	-	-	-	-	-	-	-	5
Aug. 1996	-	-	1	2	2	-	-	-	-	-	-	-	-	6

Table 23 **Incidence of natural enemies on *Apis mellifera* colonies during different months of the year**

Month	Total number of weekly observations	Number of wax moth larvae per colony	Number of adult sphinx present	Number of colonies infested by brood mites
September 1995	4	3	2	1
October 1995	5	2	-	3
November 1995	4	3	3	2
December 1995	4	-	1	4
January 1996	5	3	-	2
February 1996	4	2	-	1
march 1996	4	1	-	1
April 1996	5	1	-	-
May 1996	4	-	-	1
June 1996	4	-	-	1
July 1996	5	-	-	1
August 1996	5	1	-	-

Table 24 **Incidence of natural enemies on *Apis cerana indica* colonies during different months of the year**

Month	Total number of weekly observations	Number of wax moth larvae per colony	Number of adult wax moth present	Number of adult sphinx present
September 1995	4	4	1	-
October 1995	5	5	1	-
November 1995	4	4	-	-
December 1995	4	-	1	-
January 1996	5	5	-	-
February 1996	4	4	-	-
march 1996	4	7	-	-
April 1996	5	4	-	-
May 1996	4	-	-	-
June 1996	4	-	-	-
July 1996	5	1	-	-
August 1996	5	2	-	-

sweet potato. The adults feed on honey. The adult moth wriggles into the hive through the entrance hole in the night and feeds on the stored honey. But in *A. cerana indica* the incidence was not noticed probably due to the smaller size of the entrance hole.

4.5.4 **Brood mite (*Tropilaelaps clareae*)**

This mite had been observed to cause considerable damage to brood if not checked in time. The incidence has been observed through out the year though it was more severe during the major brood rearing season (October to January) (Table 23). The adult and nymphs suck the haemolymph of brood slowly killing them.

4.5.5 **Bee eater (*Merops orientalis*)**

These birds were seen active during the months of October to February. These were coming in large numbers, pearch on near by tree branches and catch the bees in flight. They were more threatful to *A. mellifera* and *A. cerana indica* bees were almost safe.

4.5.6 **Thai sac brood disease (TSBV)**

Only *A. cerana indica* were infected by this virus disease. TSBV infection was more severe during September to November.

4.5.7 **Robbing of *A. cerana indica* colonies by *A. mellifera***

It was some times observed that *A. mellifera* entered certain colonies of *A. cerana indica* which were kept close to each other and robbed the stored honey. Robbing was more when artificial feeding was done resulting even in the absconding of *A. cerana indica* colonies.

DISCUSSION

5. DISCUSSION

The development of an insect is conditioned by ecological factors such as humidity, temperature and food habits. In North India where *A. mellifera* has been successfully introduced where there are distinct climatic seasons, viz., winter, summer, spring and autumn. Temperature changes widely during these seasons. But in Kerala, the climate is almost uniform throughout the year. Due to this the influence of different seasons on the biology of *A. mellifera* was insignificant. But in Punjab the durations of all stages were more in winter followed by autumn and least in summer. Durations during winter varied significantly from that of the other seasons (Vashishant, 1992).

The durations of developmental stages were shorter in Kerala compared to the earlier reports from other parts of India and from outside. It may be due to the tropical conditions in Kerala with narrow escalation of maximum and minimum temperature throughout the year (Appendix II). Philips (1968) observed the egg, larval, pupal and total developmental periods of worker bee as 3, 6, 12 and 21 days respectively. While Bartholf (1972) found it as 3, 5, 13 and 24 days and for queens 3, 5, 8 and 16 days respectively.

However, the duration of different stages except larval period in Punjab were less than those in Kerala (Vashishant, 1992). The egg, larval, pupal and total developmental periods of worker bees were 2.24-2.49 days, 6.89-8.76 days, 6.33-8.27 days and 17.58-18.67 days, respectively. It could be seen that the larval period of *A.*

mellifera workers was less in Kerala compared to that in Punjab. But in the case of pupal duration it was significantly higher in Kerala. In case of drones also the larval duration was less in Kerala while total duration took more days than in Punjab. Mean egg, larval and pupal duration of *mellifera* drones were 2.28, 8.93 and 10.93 days during spring and 2.51, 9.66 and 10.29 days in autumn respectively.

The total developmental period of queen bee in Kerala (14.54 ± 0.307 days) was almost similar to earlier observations *viz,* 16 days (Philips, 1928), 14.5 days (Nelson and Sturtevant., 1924) and 16 days (Mehrotra and Bischt, 1984).

The duration of different developmental stages of Indian bees observed in the present studies matches well with previous reports from other parts of the country. Ramachandran (1939) recorded the life history of workers as 3 + 4 + 2 + = 19 days drones as 3 + 7 + 13 = 23 days and queen as 3 + 5 - 6 + 7 = 16 days. Khan and Singh (1947) found the total developmental period of worker bees as 18-19 days and that of drones 23-24 days. Naim (1983) reported the developmental period of queen as 3, 5 and 7-8 days respectively for egg, larval and pupal stages (total 15-16 days). Observations of Mehrotra and Bischt (1984) were also on par with the results of present study.

The size of eggs of both castes remained the same throughout the egg period. For *A. cerana* workers the rate of growth was more in the initial days and the growth was slow as the larvae advanced in age. But in *A. mellifera* workers the growth in size showed a steady increase.

The increase in size of drone larvae during the first two days was more compared to that of workers. This might be due to the higher quantities of royal jelly fed to them. The larval duration was observed to be more or less same for both *A. mellifera* and *A. cerana indica* bees, but the gain in size of the larvae with age was considerably higher in *A. mellifera*.

Honey flow season in Kerala coincides with the refoliation stage of rubber (*Hevea braziliensis*, Euphorbiaceae). During this stage nectar is secreted through the extrafloral nectaries present at the tip of the leaf petiole. This is the only source of honey in Kerala that is exploited commercially. Normal leaf fall in rubber occurs during December and January. This is the end of brood rearing season. During brood rearing season the bee flora available were little. Hence artificial feeding of sugar syrup was done to maintain the bee strength. Despite this there was a continuous decline in brood area and egg laying rate. During the beginning of honey flow season the brood area of the colonies were at minimum. Thereafter a continuous increase was observed.

Studies conducted at Ludhiana revealed that heavy blooming of Brassica, Peach, early Eucalyptus and Buddeling in January and February stimulated brood rearing among bees (Atwal and Goyal 1970). This was followed by citrus, bottle brush, guava, cauliflower etc. in March. Berseem (Egyptian clover) produced flowers soon after and continued upto the end of May and was the major source of surplus honey in Ludhiana. It was closely followed by Lucerne. They also observed that there was steep fall in brood area in the second half of August which continued upto the end

of December in a similar manner as that of Kerala. But there was enough bee flora to build up bee strength from January to March and the bee strength would be higher during surplus honey flow season in Ludhiana (March to May). However in Kerala the pre-honey flow season bee flora availability is nominal. This may be the prime reason for low yield of honey (20 kg per colony) in Kerala compared to higher yields in other states.

In Kerala maximum number of eggs laid per day was observed as 715 to 718 eggs during the peak period which is far less compared to that reported from other parts of the country as well as from outside. The laying rate of *A. mellifera* queen varied from 1500 to 3000 eggs per day in the peak of the season in Western countries (Kshirsagar, 1904 ; Snodgrass, ; 1925 Andrews, 1969). Sharma (1958) observed egg laying capacity of *A. mellifera* as 1500 to 2000 eggs per day during the height of brood rearing period at Lyllapur. Farrar (1967) observed the egg laying rate as 1500 eggs per day and 25000 eggs per year. Adalakha (1972) reported the number of eggs laid in Nagrota (India) was 871 to 1368 eggs per day and the maximum brood rearing was observed during March to April. Goyal (1978) observed the maximum population of *A. mellifera* in Punjab in the month of May and minimum during August.

Eventhough the daily egg laying rate of Indian bees was less in Kerala, the total number of eggs laid in an year was almost equal to that found in other parts of India. Sharma (1951) found that the queens were capable of laying 700 to 800 eggs per day during the height of brood rearing season. The total number of eggs laid in an year ranged from 76276 to 112112 with an average of 92912. Sharma (1958) reported that

in case of *A. cerana indica* brood rearing was suspended from November and the activity was resumed from January-February. Similarly Naim (1983) reported the egg laying rate ranged from 0 to 950. Mahrotra and Bischt (1984) reported that the rate of egg laying by *A. cerana indica* queen ranged between 350 and 1000 eggs per day. This type of wide variation was not noticed in Kerala, the range being narrow, ie 211 and 279. The maximum brood rearing activity was observed during the months of September, November and January. The activities were minimum during December, April and May. The decreased egg laying rate in April and May may be due to the high temperature during summer.

The studies showed that the *mellifera* queens were more prolific than *indica* queens but the performance of the former in Kerala did not match with that recorded elsewhere. This indicates the necessity of improving the management practices to induce the mellifera queens to better their egg laying rate.

The longevity of bees born on April 10 was lower than those born on June 15. April and May are the hottest months in Kerala. Also these were the months immediately followed the honey flow season. As observed by Sharma and Garg (1984) this short life span could be due to the possibility that either the bees commenced early foraging and most of them turned water carriers and perished or died as house bees in their efforts of cooling and ventilating the hives. Free and Spencer Booth (1959) found the longevity of June born bees as 28 days and that of bees born on March as 35 days. Kumar (1972) observed the mean longevity of April born bees in the subtemperate region of Himachal Pradesh as 28.46 ± 1.45 and 35.076 ± 0.52 days

respectively. According to the above authors June was the hottest month and hence the low longevity.

Pradeep and Goyal (1992) observed the longevity of April 5 born bees in Ludhiana as 28.8±0.9 days. The results of the present as well as those of the earlier studies were identical. But in Punjab the longevity of bees was less in monsoon (26.8 days) as reported by Vashishant (1992).

Results presented in Table 18 shows that the longevity of bees born on April 11 and June 16 exhibited no significant difference. Similarly the longevity of *A. cerana indica* workers was more than that of *A. mellifera* workers. The maximum life span of both mellifera and cerana were found to be almost similar. But 50 per cent mortality was observed earlier in *A. mellifera* (24 th day for bees born on April 10 and 31st day for bees born on April 15) than that in *A. cerana indica*. (37th day and 35th day in case of bees born on April 11 and June 16 respectively). These observations indicated that being a native species, *A. cerana indica* is well adapted to the Kerala ecosystem.

The present study showed that only *Vespa orientalis* occurred as a serious predator of bees in Kerala. Its incidence was restricted mainly to the period from May to December. The results are on par with the reports from in other parts of the country. The peak predatory activity occurs in August -September in the Kashmir valley, Kangra valley (Himachal Pradesh), Pathankot (Punjab) and Pune (Maharastra).

The incidence of wax moth (*Galleria mellonella*) was severe in *A. cerana indica* than that in *A. mellifera*. Goyal (1978) explained the reason for it as a peculiarity of *A. mellifera*. The workers of *A. mellifera* have the habit of collecting more propolis and mix it with wax and also seal the crevices with propolis. Hence the wax moth does not flourish in the combs.

SUMMARY

6. SUMMARY

An investigation was carried out at the apiary of Kerala Agricultural University, College of Agriculture, Vellayani, during the period from September 1995 to August 1996 to generate detailed basic information on the biology, biometrics and natural enemies of Indian and Italian bees under Kerala conditions. The yellow strain of Italian bee, *Apis mellifera ligustica* Spin. and Indian bees, *Apis cerana indica* were used for this study. The results of the investigations are summarised below.

The eggs of *A. mellifera* hatched on third day. The larval period of worker bees ranged from 5.82 ± 0.101 days during lean season (May to August) to 5.93 ± 0.131 days in honey flow season (February to April). The pupal period varied from 10.55 ± 0.35 days in brood rearing season (September to January) to 11.15 ± 0.261 days in honey flow season. Total period to complete development took 20.06 ± 0.313 days in honey flow season and 19.6 ± 0.242 days in brood rearing season.

In case of *A. mellifera* drones, egg period ranged from 2.81 ± 0.379 to 2.88 ± 0.063 days. The larval period ranged from 6.96 ± 0.187 days in brood rearing season to 7.17 ± 0.162 days in lean season. The pupal period was 13.41 ± 0.395 days during brood rearing season and 13.28 ± 0.28 days in lean season. Total period of development worked out to be 23.53 ± 0.256 days in lean season and 23.24 ± 0.403 days in brood rearing season.

The mean egg, larval, pupal and total developmental period in case of *A. mellifera* queen were 2.68 ± 0.069, 4.66 ± 0.215, 7.2 ± 0.126 and 14.54 ± 0.307 days respectively.

In *A. cerana indica* the mean duration of the egg stage of worker bees varied from 2.92 ± 0.039 days in lean season to 2.96 ± 0.069 days in honey flow season. During brood rearing season, it was 2.94 ± 0.089 days. Larval period was 5.86 ± 0.098 days in lean season and 5.91 ± 0.097 days in honey flow season. The pupal period ranged from 10.17 ± 0.063 days in lean season to 10.2 ± 0.208 days in brood rearing season. Total developmental period took 18.89 ± 0.15 days in honey flow season, 19.00 ± 0.402 days in brood rearing season and 19.11 ± 0.062 days in lean season.

In the case of drones the egg period was 2.85 ± 0.084 and 2.99 ± 0.075 days during brood rearing season and lean season respectively. Larval period lasted for 6.95 ± 0.146 days in brood rearing season and 7.09 ± 0.149 days in lean season. Pupal period was completed in 12.99 ± 0.246 days during brood rearing season and 13.23 ± 0.123 days in lean season. The whole period of development took 22.77 ± 0.22 days in brood rearing season and 23.34 ± 0.308 days in lean season.

The total developmental period of queen bees took 14.74 ± 0.564 days in lean season and 14.76 ± 0.196 days in brood rearing season. The egg, larval and pupal period were 2.8 ± 0.178, 4.84 ± 0.23 and 7.12 ± 0.24 days respectively.

The egg size of different castes of both the bees remained the same throughout the egg period. The sizes (length x breadth) of 1, 2, 3, 4 and 5 days old worker larvae were 2.06 x 0.59, 4.67 x 1.22, 7.63 x 2.41, 10.58 x 3.64 and 13.75 x 5.01 for *A. mellifera* and 1.93 x 0.55, 5.46 x 1.78, 7.98 x 2.034, 7.4 x 3.79 and 8.81 x 4.22 mm for *A. cerana indica* respectively.

The sizes of larvae increased from 3.4 x 0.83 mm in the very first day of hatching to 16.68 x 7.21 mm in the sixth day in drones of *A. mellifera* and from 2.58 x 0.7 mm to 11.75 x 6.97 mm in case of drones of *A. cerana indica*. The size increase continued upto first day after capping in both the castes.

Average number of eggs laid by *A. mellifera* per day ranged from 162 in December to 718 in August. The average annual performance was 184430 eggs. *A. cerana indica* queens laid on an average 247 eggs daily and 88086 eggs in an year.

The mean longevity of *A. mellifera* workers ranged from 28.22 ± 1.602 days for April 10 born bees to 30.97 ± 1.52 days for June 16 born bees. The longevity of *A. cerana indica* workers ranged from 33.46±3.575 days for April 11 born bees to 33.32 ±2.546 days for June 15 born bees. The mean longevity of *A. cerana indica* drone bees born on April 11 was 34.58±2.45 days.

Among the natural enemies, hornets, wax moth, mite, bee eater birds and death head moths were observed in *A. mellifera* colonies. Hornet (*Vespa orientalis*)attack was more during May to December between 7 A.M and 10 A.M of the day. Wax moth

(*Galleria mellonella*) larvae were observed during brood rearing season. Death head moth (*Acherontia styx*) were observed from September to November. Brood mite (*Tropilaelaps clarae*) was observed throughout the year though it was more severe during major brood rearing season. The bee eater birds (*Merops orientalis*) were seen active during the months of October to February.

In *A. cerana indica* colonies hornets, wax moth and Thai sac brood disease were observed. Hornet and wax moth incidence followed the same pattern as in *A. mellifera*. Thai sac brood virus disease was more severe during September to November. No brood mite infestation was noticed.

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APPENDICES

APPENDIX I

Status of Apiculture in Kerala

Year	Number of farmers	Number of colonies	Honey production (kg)
1972	220	450	900
1973	300	825	1000
1974	550	2100	10000
1975	800	5000	25000
1976	1400	8400	40000
1977	3000	18250	175000
1978	8000	56000	360000
1979	12500	85625	500000
1980	15000	120000	600000
1981	20000	180000	700000
1982	23400	236000	700000
1983	42000	470000	920000
1984	49000	520000	1012000
1985	53000	680000	920000
1986	58000	800000	1011000
1987	67000	840000	1220000
1988	76000	1075000	1080000
1988	82000	1172000	1140000
1990	88000	1698000	914000
1991	88000	12140	17200

Source - Kerala Karshakan . 1994 **2** : 8

APPENDIX II

Weather data during the experimental period (September 1995 to August 1996)

Month	Max. temp.	Mini. temp.	Rainfall (mm)	Relative humidity
Sept. 95	27.8	25.1	219.4	92
Oct 95	28.1	25.3	100.5	93
Nov. 95	22.4	26.2	138.4	94
Dec. 95	23.6	24.3	0.0	91
Jan. 96	25.0	25.8	0.0	91
Feb. 96	34.2	25.7	14.0	90
Mar. 96	35.5	26.4	4.3	72
Apr. 96	32.6	27.5	28.6	95
May 96	32.2	28.2	91.4	70
June 96	30.0	26.3	323.0	91
July 96	28.1	26.8	329.5	72
Aug. 96	29.8	26.5	385.8	69

Source : Dept. of Agronomy, College of Agriculture, Vellayani.

BIOLOGY AND BIOMETRIC STUDIES ON *Apis cerana indica* F. AND *Apis mellifera ligustica* Spin.

By

AJITHKUMAR, T.N.

ABSTRACT OF THESIS
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THIRUVANANTHAPURAM
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ABSTRACT

With a view to generate detailed basic information on the biology, biometrics and natural enemies of Indian and Italian bees in Kerala an experiment was carried out at the Apiary of Kerala Agricultural University, College of Agriculture, Vellayani, from September 1995 to August 1996. The yellow strain of Italian bees, *Apis mellifera linguistica* L. and Indian bees *Apis cerana indica* were used for the study. An abstract of the result is given below.

In all the castes the egg period took almost 3 days. The larval period of *A. mellifera* workers ranged from 5.82 to 5.93 days, the pupal period ranged from 10.55 to 11.15 days and total developmental period from 19.6 to 20.66. The larval period of drones took 6.96 to 7.17 days, pupal period took 13.14 to 13.28 days and total developmental period took 23.54 to 25.53 days. The mean larval period of *A. cerana indica* workers varied from 5.86 to 5.91 days, pupal period varied from 10.17 to 10.20 days and total developmental period varied from 18.89 to 19.11 days . The larval period of drones ranged from 6.95 to 7.09 days, pupal period ranged from 12.99 to 13.23 days and total developmental period ranged from 22.77 to 23.34 days. The mean larval , pupal and total developmental period in case of *A mellifera* queens were 4.66, 7.2 and 14.54 days and in case of *A. cerana indica* 4.84, 7.12 and 14.74 days respectively.

The egg size of different castes of both the bees remained the same throughout the egg period. The sizes (length x breadth) of 1, 2, 3, 4 and 5 days old worker larvae

were 2.06 x 0.59, 4.67 x 1.22, 7.63 x 2.41, 10.58 x 3.64 and 13.75 x 5.01 for *A. mellifera* and 1.93 x 0.55, 5.46 x 1.78, 7.98 x 2.34, 7.98 x 3.79 and 8.81 x 4.22 mm for *A. cerana indica* respectively. The sizes of larvae increased from 3.4 x 0.83 mm in the very first day of hatching to 16.68 x 7.21 mm in the sixth day in drones of *A. mellifera* and from 2.58 x 0.7 mm to 11.75 x 6.97 mm in case of drones of *A. cerana indica*. The size increase continued upto first day after capping in both the castes.

Mean average eggs laid by *A. mellifera* ranged from 162 in December to 718 in August. The average annual performance was 184430 eggs. *A. cerana indica* queens laid on an average 247 eggs daily and 88086 eggs in an year.

The mean longevity of *A. mellifera* workers ranged from 28.22 days for April 10 born bees to 30.97 days for June 16 born bees. The longevity of *A. cerana indica* workers ranged from 33.46 days for April 11 born bees to 33.32 days for June 16 born bees. The mean longevity of *A. cerana indica* drone bees born on April 11 was 34.58 days.

Among the natural enemies, hornets, mite, bee eater birds and death head moths were observed in *A. mellifera* colonies. Hornet (*Vespa orientalis*)attack was more during May to December between 7 A.M and 10 A.M of the day. Few wax moth (*Galleria mellonella*) larvae were observed during brood rearing season though no damage was noticed. Death head moth (*Acherontia styx*) were observed from September to November. Brood mite (*Tropilaeps clarae*) was observed throughout

the year though it was more severe during major brood rearing season. The bee eater birds (*Merops orientalis*) were seen active during the months of October to February.

In *A. cerana indica* colonies hornets, wax moth and Thai sac brood disease were observed. Hornet and wax moth incidence followed the same pattern as in *A. mellifera*. Thai sac brood virus disease was more severe during September to November.