BIOLOGY AND LIFE-FECUNDITY OF PULSE BEETLE (*Callosobruchus chinensis* Linn.) ON DIFFERENT PULSES

By

KAMBLE SHAMKANT MANOHAR

B.Sc. (AGRI.)

MASTER OF SCIENCE
(AGRICULTURE)
IN
AGRICULTURAL ENTOMOLOGY

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
COLLEGE OF AGRICULTURE, LATUR
MARATHWADA AGRICULTURAL UNIVERSITY, PARBHANI

2008

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DISSERTATION

Submitted to
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(AGRICULTURE)
IN
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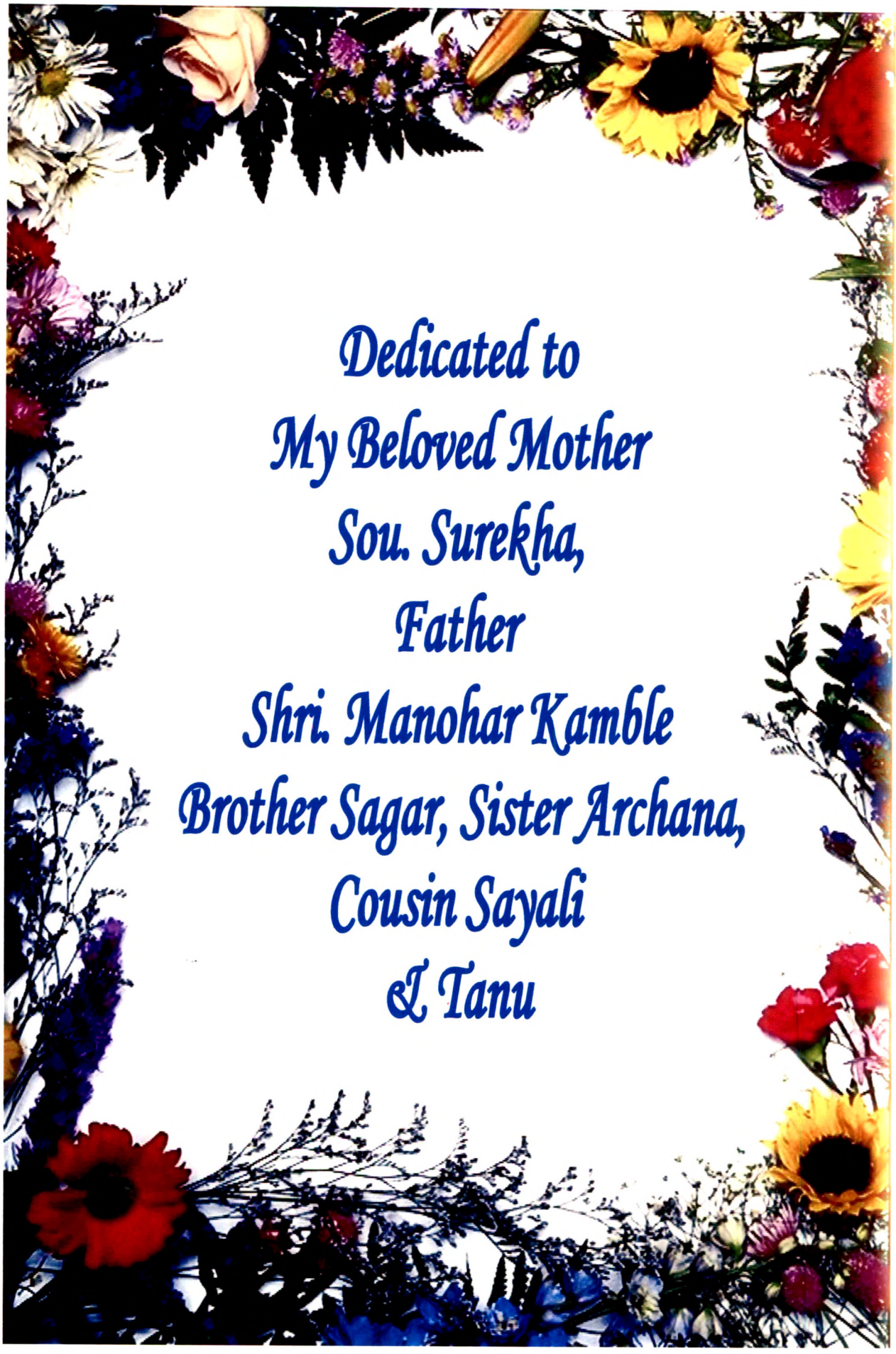
Dedicated to
My Beloved Mother
Sou. Surekha,
Father
Shri. Manohar Kamble
Brother Sagar, Sister Archana,
Cousin Sayali
& Tanu

CANDIDATE'S DECLARATION

I hereby declare that the dissertation

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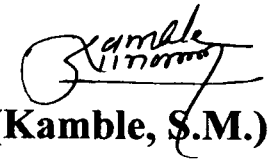
any University.



Place : Latur

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Date : 17/5/ 2008

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CERTIFICATE – I

This is to certify that the dissertation entitled **"BIOLOGY AND LIFE-FECUNDITY OF PULSE BEETLE (*Callosobruchus chinensis* Linn.) ON DIFFERENT PULSES"** submitted by Shri. **KAMBLE SHAMKANT MANOHAR** to the Marathwada Agricultural University, Parbhani in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **AGRICULTURAL ENTOMOLOGY** is record of original and bonafide research work carried out by him under my guidance and supervision. It is of sufficiently high standard to warrant its presentation for the award of the said degree.

I also certify that the dissertation or part thereof has not been previously submitted by him for a degree of any university.

Place : Latur
Date : 17/5/ 2008.

(P.K. Nalwandikar)
Research Guide
&
Chairman
Advisory committee

CERTIFICATE – II

This is to certify that the dissertation entitled "**BIOLOGY AND LIFE-FECUNDITY OF PULSE BEETLE (*Callosobruchus chinensis* Linn.) ON DIFFERENT PULSES**" submitted by Shri. **KAMBLE SHAMKANT MANOHAR** to the Marathwada Agricultural University, Parbhani in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **AGRICULTURAL ENTOMOLOGY** has been approved by the student's advisory committee after viva-voce examination in collaboration with the external examiner.

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Place : Latur

Date : . .2008 ***(Kamble S.M.)***

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ABBREVIATIONS

%	-	per cent
C. analis	-	*Callosobruchus analis*
C. chinensis	-	*Callosobruchus chinensis*
C. maculatus	-	*Callosobruchus maculatus*
C.D.	-	Critical difference
C.V.	-	Coefficient of variation
cm	-	Centimeter(s)
Edn.	-	edition
et al.	-	*et alia,* and others
Fig	-	Figure
gm	-	gram
i.e.	-	*id est,* that is
log	-	logarithm
m	-	meter
Max.	-	Maximum
Met.	-	Meteorological
Min.	-	Minimum
mm	-	Millimeter(s)
N.S.	-	Non-significant
No.	-	number (s)
°C	-	degree celcious
PP	-	pages
R H	-	Relative humidity
S.D.	-	Standard deviation from mean
S.E.	-	Standard error
sp.	-	species
Temp.	-	Temperature
viz.,	-	Videlicet, namely

INTRODUCTION

Chapter I

INTRODUCTION

India is the largest producer and consumer of pulses in the world accounting for 33 per cent of the world area and 22 per cent of world production of pulses. The domestic demand and consumption however, is much higher than production mainly because of pulses are major source of protein for large section of the vegetarian population in the country. The yield of pulses in India is low at around 550 to 625 kg per hectare as against 1600 kg in United States, 1140 kg in China and world average of 900 kg per hectare. In Maharashtra it was grown on an area of 38.28 lakh hectares with annual production of 23.04 lakh tonnes and average yield of 602 kg per hectare during 2006-07(Anonymous, 2008).

The important pluses are gram (*Cicer arietinum*), arhar (*Cajanus cajan* L.), urd (*Vigna mungo* L.), mung (*Vigna radiata*), lentil (*Lens culinaris* Medic) and cowpea (*Vigna unguiculata* L.).Pulses are the most important part of our diet as pulses are the richest source of protein amongst the food grains. They are not only the rich source of protein but they consist of many important amino acids than the cereal proteins. Pulses are rich in vitamin A, B-1and vitamin C. They are also better source of minerals specially Ca. The Ca content in gram is 0.19 per cent in urd it is 0.21 per cent and in mung it is 0.15 per cent. (Singh, 2005).

Important pests infesting stored pulses are *C. chinensis* L., *Pachymerus quadrimaculatus* Fabr., Bruchus *analis* Fabr. ,*B.albocallosus* Pic, *B. phaseoli* Gyll., *Laria affinis* Frol., *Laria emarginatus* and *Laria pisorum* Linn.(Pruthi and Singh,1950) Among them *Callosobruchus*

chinensis Linn. is an injurious and common pest of pulses (Singh and Verma, 2003).

Pulse bettle belongs to family Bruchidae and order Coleoptera. It causes serious damage to pulse grain during storage not only in forms of quantity but also in quality (Singh and Pande, 2001). The losses caused by pulse beetle, *C. chinensis* have been reported to the extent of 55.20 per cent in chickpea Gupta *et al.* (1981). The damage to cowpea seeds is so serious that the entire seed material is eaten by the beetle leaving only the seed coats with empty cavities (Singh and Sharma, 2003).

Ramzan *et al.* (1990) reported 69.3 per cent losses due to pulse bettle, *C. maculatus* in cowpea during storage. Borikar *et al.* (1977) found 4.5 per cent weight loss in chickpea due to *C. chinensis* in Marathwada. Dias and Yadav (1988) reported losses in seeds of pigeonpea, cowpea, green gram, chickpea and black gram to the tune of 14.65, 14.36, 10.08, 9.38 and 3.47 per cent due to *C. chinensis* infestation.

C. chinensis breeds exclusively on variety of pulses and having a very short life span with high degree of reproductive potential (Singh *et al.*, 2003). The present investigation was carried out during 2006-2007 with the following objectives.

1. To study the biology of *Callosobruchus chinensis* (Linn.) on different pulses under laboratory conditions.
2. To study the life-fecundity tables of *Callosobruchus chinensis* (Linn.) on different pulses.

REVIEW OF LITERATURE

Chapter II

REVIEW OF LITERATURE

The literature pertaining to the various aspects of the present study have been thoroughly reviewed and presented under following heads.

2.1 Biology of pulse beetle, *Callosobruchus chinensis* on different pulses.

2.2 Fecundity of pulse beetle, *Callosobruchus chinensis* on different pulses.

2.1 Biology of pulse beetle, *Callosobruchus chinensis* on different pulses

2.1.1 Incubation period

Singh (1962) observed that incubation period of *Pachymerus chinensis* (L.) was 134 to 139 hours on different pulses under study at room temperature.According to Rajak and Pandey (1965), incubation period of *C. chinensis* lasted for 3 to 18 days. Raina (1970) reported that the average incubation period of *C. chinensis* at 30^0C and 90 per cent relative humidity on mung bean was 3 to 5 days.

Ahmed *et al.* (1978) observed that the average incubation period of *C. chinensis* was 5.39 days on broad bean seeds (*Vicia feba* L.). According to Pandey and Singh (1997), the incubation period of *C. chinensis* lasted for 4 to 5 days on urd (*Vigna mungo*) and chickpea (*Cicer arietinum*) seeds. Gill and Ramzan (1998) reported that the minimum incubation period of *C. maculatus* on green gram was 3.46 $\pm$ 0.05 days during July.

Singh and Rina Kumari (2000) reported that the incubation period of *C. chinensis* on cowpea and gram seeds was 4 to 5 days at

28 ± 2^{0}C temperature and 70 to 75 per cent relative humidity. Singal and Borah (2001) observed that the incubation period of *C. chinensis* on *Cajanus cajan* pods was 6.8 ± 0.13 days. Bhargava *et al.* (2008) reported 4.40 days incubation period of *C. chinensis* on cowpea and 7.20 days on soybean.

2.1.2 Per cent egg hatching

According to Raina (1970), hatching of *C. chinensis* ranged from 94 to 99 per cent on mungbean at 30^{0}C temperature and 70 per cent relative humidity. Gill and Ramzan (1998) studied the egg hatchability of *C. maculatus* on green gram in Punjab. According to them it varied from 57.9 per cent in November to 93.1 per cent in September. Singh and Rina Kumari (2000) observed that the eggs of *C. chinensis* laid on last day were non-viable.

2.1.3 Larval-pupal period

Singh (1962) observed that combined larval and pupal period of *Pachymerus chinensis* (L.) was 18.9 to 38.3 days on different pulses at room temperature. Rajak and Pandey (1965) observed that the larval and pupal stages of *C. chinensis* passed inside the seed with it's average larval and pupal period to the extent of 29 and 6 to 21 days in various seasons.

According to Raina (1970) the combined larval and pupal periods of *C. chinensis* on mung bean was 18.8 days. Ahmed *et al.* (1978) reported that the average larval and pupal period of *C. chinensis* were 16.57 and 7.31 days, respectively on broad bean seeds (*Vicia feba* L.). Pandey and Singh (1997) found that the combined larval and pupal period

of *C. chinensis* on urd (*Vigna mungo*) and chickpea (*Cicer arietinum*) seeds ranged from 20 to 28 days.

According to Gill and Ramzan (1998) larval and pupal period of *C. maculatus* on green gram was 10.60 ± 0.06 and 5.02 ± 0.66 days, respectively. Singh and Rina Kumari (2000) reported that the combined larval and pupal period of *C. chinensis* on cowpea and gram seed at room temperature was averaged 20 days.

Singal and Borah (2001) observed that larval and pupal period of *C. chinensis* was 16.2 ± 0.16 days and 7.2 ± 0.18 days, respectively on pods of *Cajanus cajan*. They also reported an average pre-oviposition period of 7.8 ± 0.46 hours on pods of *Cajanus cajan*.

Bhargava *et al.* (2008) reported that the mean larval and pupal period of *C. chinensis* ranged from 14.80 to 26.20 days and 5.40 to 11.40 days ,respectively on different pulses. They also reported that the developmental period of *C. chinensis* varied from 24.60 to 44.80 days on different pulses including cowpea, mung, moth, gram, pigeonpea, pea and soybean.

2.1.4 Per cent adult emergence

Shrivastava and Bhatia (1958) studied the effect of food on development of *C. chinensis* and they observed that emergence of adult took place only in cowpea, broad bean, chickpea and garden pea. Whereas, the larval death was observed when fed on sword bean, hycinth bean, kidney bean and soybean. Gokhale (1973) reported adult emergence of *C. maculatus* to the extent of 77.47 to 86.44 per cent when reared on chickpea and bengal gram.

The adult emergence of *C. maculatus* in chickpea was observed to be 20.83 to 50.29 per cent by Jadhav *et al.* (1984). Manohar

and Yadav (1990) reported adult emergence of *C. chinensis* to the extent of 72.00 to 96.00 per cent on cowpea. Bhargava *et al.* (2008) observed that the adult emergence of *C. chinensis* was 76.45 per cent on soybean and 86.27 per cent on cowpea.

2.1.5 Life span

Rajak and Pandey (1965) reported that the life-cycle duration of *C. chinensis* varied from 17 to 114 days in different seasons. Atwal *et al.* (1968) found that *C. analis* required 21.89 days for completion of it's life cycle. Ahmed *et al.* (1978) observed the life – span of *C. maculatus* male and female to the extent of 7.10 and 6.70 days, respectively.

Kim and Choi (1987) reported that the developmental period of *C. chinensis* was 29 days on azuki bean (*Vigna angularis*) and 31 days on mung bean (*Vigna radiata*) at 25^0C. Prabha and Sehgal (1990) reported the longevity of female *C. chinensis* to the tune of 8 days. Sison *et al.* (1996) reported that *C. chinensis* completed its life cycle from eggs to emergence of adult in 21 to 30 days on mung bean.

Dhepe *et al.* (1993) and Singh and Pandey (1994) reported that the longevity of both sexes of *C. chinensis* was not significantly affected by different varieties of green gram and gram, respectively. Gill and Ramzan (1998) observed life span of *C. maculatus* to the tune of 19.0 days during June to July and to the highest extent of 35.35 days during October to November in Punjab.

Singal (1998) found that *C. chinensis* completed its life-cycle from egg laying to adult emergence in an average period of 34.5 days under field condition as compared to 35.5 days under laboratory condition.

Singal and Borah (2001) studied biology of *C. chinensis* on pods of *Cajanus cajan* and they reported that an average adult longevity of male and female was 6.2 ± 0.36 and 6.8 ± 0.25 days, respectively. They also observed average total developmental period of 30.4 ± 0.62 days.

Bhargava *et al.* (2008) noted the longevity of male and female beetles of *C. chinensis* varied from 6.20 to 8.80 days and 5.60 to 8.40 days, respectively, being minimum in soybean and maximum on cowpea in both the sexes.

2.1.6 Sex ratio

The sex ratio of *C. maculatus* was observed to be 1: 0.93 and 1: 1 when reared on chick pea and bengal gram, respectively (Gokhale, 1973). Begum *et al.* (1979) recorded sex ratio of *C. chinensis* to the tune of 1:1 each on mung, gram and pea.

While, Manohar and Yadav (1990) recorded sex ratio of *C. maculates* 1:0.93 to 1:1.40 when reared on different varieties of cowpea.

2.1.7 Growth Index

The growth index of *C. maculatus* was reported to be 2.68 to 3.14 when reared on chick pea and bengal gram (Gokhale, 1973). According to Singh *et al* (1980) and Manohar and Yadav (1990), the growth index of *C. chinensis* and *C. maculatus* ranged from 2.67 to 5.15 and 2.54 to 4.11, respectively on different pulses including cowpea. Bhargava *et al.* (2008) recorded the growth index of *C.chinensis* to the maximum extent of 3.51 on cowpea followed by mung (3.06), moth (2.38), gram (2.39), pigeon pea (2.16) and soybean (1.71).

2.2 Fecundity of pulse beetle, *Callosobruchus chinensis* on different pulses

Takasugi (1924) reported that egg laying of *Bruchus chinensis* at atmospheric condition was 70-80 eggs. EL Sawaf (1956) reported that the highest number of eggs (75) were laid by a single female of *C. maculatus* on chickpea.

Howe and Currie (1964) studied the oviposition of several species of bruchidae and observed that on average of 45 eggs with a range of 20 to 64 eggs were laid at 30^0C and 80 per cent relative humidity. According to Rajak and Pandey (1965), a female *C. chinensis* laid 50 to 103 eggs in her life-time.

Raina (1970) noted that *C. chinensis* females laid an average of 78 eggs with a range of 63 to 90 over a period of 8 days. However, the maximum daily eggs per day (30 eggs / female) occurred in the first 24 hours.

Thanthianga and Mitchell (1990) studied laboratory experiments carried out at ambient light and temperature (22-24^{0}C). The fecundity of the south India strain of *C. maculatus* was 73 eggs for females developed in 31 days and increased to 94 eggs for females emerged after 41 days.

Prabha and Sehgal (1990) found that newly emerged female of *C. chinensis* started laying eggs immediately after mating and continued ovipositing till the seventh day, mostly the females died on the 8th day of their emergence. Ageing had a profound effect on the fecundity and fertility of this pest. The number of eggs, either from a cross between an aged parent and young or both the aged parents, were less (21.9 to 27.8 eggs per female) than those from young parent (65.2 eggs per female).

Khare (1994) reported that egg laying of *C. chinensis* varied from 60 to 90 eggs. Borikar and Pawar (1996) studied life-fecundity tables of pulse beetle, *C. chinensis* on mung bean (*Vigna radiata*) and reported the population of *C. chinensis* increased with r_m 0.08 and λ 1.80 per day. The population multiplied 11.34 times between two successive generations with the mean time of 30.51 days for completing a generation. On reaching the stable age distribution, the population at various stages of egg, larva, pupa and adult accounted for 46.11, 45.61, 5.55 and 2.71 per cent, respectively.

Pandey and Singh (1997) studied biology of *C. chinensis* on urd (*Vigna mungo*) and chickpea (*Cicer arietinum*) seeds at 28 $\pm$ 2^0C and 70 $\pm$ 5 per cent relative humidity. According to them, an average of 70 eggs were laid by females, with it's maximum number laid on the first day of oviposition.

The studies on the biology of pulse beetles, *C. chinensis* on cowpea carried out by Singal (1998) revealed that a female laid 28.6 eggs under field condition as compared to 42.2 eggs in the laboratory conditions.

Singh and Rina Kumari (2000) studied the biology of *C. chinensis* (L.) on cowpea and gram seed at room temperature i.e. 28 $\pm$ 2^0C and 70 to 75 per cent R.H. According to them on an average 70 eggs were laid by a female with it's maximum laying on the first day of oviposition.

Bhargava *et al.* (2008) observed maximum eggs of *C. chinensis* on mung (70.20) followed by pigeonpea (69.80), gram (69.40), moth (66.40) and pea (60.00). However the minimum number of eggs (47.40) was laid on soybean.

MATERIAL AND METHODS

Chapter III

MATERIAL AND METHODS

The present studies on the biology and life-fecundity tables of pulse beetle, *Callosobruchus chinensis* Linn. was carried out at Department of Agricultural Entomology, College of Agriculture, Latur during monsoon 2006-07. The material used and techniques employed are presented under following heads.

3.1 Rearing of test insect

3.2 Biology of *C. chinensis*

3.3 Life-fecundity of *C. chinensis*

3.1 Rearing of test insect

The initial culture of the test insect was maintained on disinfected cowpea seeds at room temperature. A single pair of *C. chinensis* was obtained from the stock culture maintained in the Department of Agricultural Entomology, College of Agriculture, Latur. Clean seeds of cowpea were sterilized at temperature of 55^0C for 4 hours in the oven to eliminate the hidden infestation. Twenty five pairs of one to two days old beetles from the initial culture were released in wide mouth cylindrical plastic box measuring 20 cm x 15 cm containing 250 g seeds of cowpea. The boxes were covered with muslin cloth and fasten with rubber band. Subsequently adults emerged from this culture were used for further study. Necessary care like use of forceps and camel hairbrush was taken in handling the insects and grains.

The sexes were separated on the basis of morphological characters (Southgate, 1958), the male had pectinate antennae, while that

of female had serrate (Raina, 1970). The apical regiment was found elongate and oblong in male and bluntly rounded or ovate in female. Antennal segments were deeply serrated in male. The serration becomes more prominent from the fourth segment and onward in male and from fifth segment in female. In male the antennae move in right and left direction and they are curved towards each other. In female it moves forward and backward and they are straight. Male showed no response to touch, whereas females showed the response. The adult male and female measured about 3.2 to 3.36 and 3.43 to 3.56 mm in length (Khare, 1994).

3.2 Biology of *C. chinensis*

The biology of pulse beetle, *C. chinensis* was carried out under laboratory conditions on cowpea, mung, tur, and gram during 2006-07. Twenty five pairs of one to two days old adults of *C. chinensis* were released for egg laying in round plastic boxes (21 cm x 15 cm) containing grains of the pulses under study. The grains containing the eggs were collected on next day morning. In order to facilitate the observations. One egg was kept on each grains, while others were removed with the help of a needle. Such one hundred grains were kept individually in plastic vials (6.5 cm x 2.5 cm) under laboratory condition at fluctuating room temperature ranging from 28.9 to 29.4 ^{0}C and relative humidity of 71.0 to 70.4 per cent. The observations were taken daily in the morning. The observations on per cent hatching of eggs, incubation period, larval + pupal period, longevity of male and female, growth index and sex ratio were recorded.

The growth index was calculated by using Singh and Pant's (1955) formula.

$$\text{Growth index} = \frac{S}{T}$$

Where,

S = Percentage of adult emergence

T = Average developmental period (days)

3.3 Life-fecundity tables of *C. chinensis* on different pulses

The adults emerged on the day were paired and released in plastic vials (6.5 cm x 2.5 cm) at 1:1 sex ratio containing fifty grains of each pulses. The grains with eggs were replaced daily by healthy grains and the number of eggs laid by an individual female was recorded till all the females died.

The life-fecundity tables of *C. chinensis* on four different pulses viz., mung, gram, cowpea and tur were constructed by studying 100 eggs in a group of 20 in each replicate.

All the larvae after hatching were bored into the seed. The observations were made daily on hatching, larval - pupal development, successful adult emergence, fecundity and age-specific mortality in eggs, larvae - pupae and adults. The total number of adults emerged on a particular day were transferred to a separate cage in the ratio of 1:1 for determining the age-specific fecundity. The fresh healthy, sterilized grains were placed into plastic vials (6.5 cm x 2.5 cm) for the purpose of egg laying.

According to Southwood (1968), the number of female births (m_x) was calculated by dividing the number of eggs laid per female by two considering the sex ratio of 1:1.

The life-fecundity tables under laboratory conditions were constructed by using the following column headings proposed by Birch (1948), elaborated by Howe (1953) and Atwal and Bains (1974).

x = pivotal age in days

l_x = survival of females at age 'x'

m_x = age schedule for female births at age 'x'

3.3.1 Net reproductive rate

The value of 'x', 'l_x' and 'm_x' was calculated from the data on life-tables. The sum of products '$l_x m_x$' is the net reproductive rate represented by R_o (Lotka, 1925). The net reproductive rate is the rate of multiplication of the population in each generation measured in terms of females produced per generation. The number of times a population would multiply per generation was calculated by the following formula.

$$R_0 = \Sigma l_x m_x$$

3.3.2 Mean generation time

The precise value of cohort generation time (T_c) is the mean age of mothers in a cohort at the birth of female offspring. It was calculated as follows.

$$T_c = \frac{\Sigma l_x m_x x}{R_0}$$

3.3.3 Innate capacity for increase in numbers

The number of individuals survived and mean number of female offsprings produced at each age interval was recorded. From the data on life-table, the arbitrary value of innate capacity for increase in number 'r_c' was calculated by using following formula (Loughlin, 1965).

$$r_c = \frac{\text{Log}_e R_o}{T_c}$$

The intrinsic rate of natural increase (r_m) was then calculated from the value of arbitrary 'r_m' by taking two trial values arbitrarily selected on either side of it differing in second decimal place by interpolation with formula given by Birch (1948) and Watson (1964).

$$\Sigma e^{7-rmx} l_x m_x = 1096.6$$

Table was then constructed with column 'x' and '$l_x m_x$' for each trial 'r_m'. The two trial values of $\Sigma e^{7-rmx} l_x m_x$ were then plotted on the horizontal axis against their respective arbitrary 'r_m' on the vertical axis. The points were joined to give a line which intersected a vertical line drawn from the desired values of $\Sigma e^{7-rmx} l_x m_x = 1096.6$. The point of intersection gave the value of true 'r_m' accurate to four decimal places. The precise generation time (T) was then calculated from the equation :

$$T = \frac{\text{Log}_e R_o}{r_m}$$

3.3.4 The finite rate of natural increase (λ)

The finite rate of natural increase (λ) i.e. females per female per day was calculated as:

$$\lambda = \text{anti log}_e r_m$$

3.3.5 Stable age-distribution

The stable age-distribution (per cent distribution of various age groups) is the distribution, which would be reached by a population of stable age schedule of birth rate and death rate (m_x and l_x) when grown in a limited space (Andrewartha and Birch, 1954). The stable

age-distribution was worked out with the knowledge of 'r_m' and the age-specific mortality of the immature as well as mature stages. The L_x (life-table age-distribution) was calculated from the 'l_x' table with the formula as follows.

$$Lx = \frac{l_x + (l_x + 1)}{2}$$

The L_x was multiplied with $e^{-rm\ (x+1)}$ and the percentage distribution of each pivotal age (x) was worked out. By putting together the percentages under each pivotal age for respective stages viz., egg, larva, pupa and adult, the expected percentage distribution of each stage in a stable age-distribution was calculated.

RESULTS

Chapter IV

RESULTS

The present studies on the biology and life-fecundity tables of pulse beetle, *Callosobruchus chinensis* Linn. on different pulses was carried out at the Department of Agricultural Entomology, College of Agriculture, Latur during monsoon, 2006-2007. The results obtained in the present investigation are presented under the following headings.

4.1 Biology of *Callosobruchus chinensis* (Linn) on different pulses

4.2 Life-fecundity tables of *Callosobruchus chinensis* (Linn) on different pulses

4.1 Biology of *Callosobruchus chinensis* (Linn) on different pulses

4.1.1 Egg

The data on incubation period revealed that the differences in the incubation period were non-significant (Table 1) when the *C. chinensis* were reared on different pulses. The mean incubation period varied from 4.18 to 4.43 days. The minimum mean incubation period of 4.18 days was observed on tur grains and maximum of 4.43 days on cowpea grains. The data on the percentage egg hatch was also non-significant. The egg hatching was 95.0, 95.0, 97.0 and 98.0 per cent on cowpea, tur, mung and gram, respectively.

Table 1 : The mean incubation period, per cent egg hatch, larval-pupal duration and growth index of *C. chinensis* on different pulses

Different food grain (pulses)	Mean incubation period (days)	Per cent egg hatch	Larval pupal period (days)	Growth index
Cowpea	4.43	95.00 (75.93)	26.60	2.69
Mung	4.21	97.00 (76.53)	26.00	2.68
Tur	4.18	95.00 (75.93)	26.31	2.69
Gram	4.31	98.00 (76.88)	18.98	2.72
S. E. ±	0.063	1.90	0.28	0.071
C.D. at 5%	N.S.	N.S.	0.84	N.S.
C.V. (%)	3.30	5.57	1.19	5.90

Figures in parentheses indicate arcsine transformed values.

4.1.2 Larva - pupa

The data on larval-pupal duration showed significant differences (Table 1). The highest larval-pupal duration (26.60 days) was recorded when *C. chinensis* were reared on cowpea grains and it was at par when reared on mung (26.00 days) and tur (26.31 days). The significantly lowest larval-pupal period was recorded on gram (18.98 days).

The statistically non significant differences were observed in respect of growth index of *C. chinensis* on different pulses (Table 1). However, the highest growth index (2.72) was observed when it was reared on gram and lowest (2.68) when reared on mung grains.

4.1.3 Adult

The differences in mean life cycle duration of male, female and in general *C. chinensis* were significant (Table 2) when fed on different pulses. The significantly lowest life-cycle duration was recorded for male (23.10 days), female (23.48 days) and in general (23.29 days) when *C. chinensis* were reared on gram grains. The significantly longer life-cycle duration of female (30.70 days) and in general (30.49 days) was observed when *C. chinensis* reared on tur. In males also life-cycle duration was highest (30.28 days) when reared on tur however, it was at par with mung (30.10 days) and cowpea (30.05 days).

Table 2 : The mean life-cycle duration of *C. chinensis* on different pulses

Pulses	Life-cycle duration (days)		
	General	Male	Female
Cowpea	30.03	30.05	30.01
Mung	30.21	30.10	30.32
Tur	30.49	30.28	30.70
Gram	23.29	23.10	23.48
S. E. ±	0.24	0.47	0.25
C.D. at 5%	0.94	1.42	0.77
C.V. (%)	0.17	3.73	2.01

The data on the per cent adult emergence (Table 3) was non significant. The per cent adult emergence in male varied from 39 per cent (gram) to 43 per cent (mung). In females adult emergence varied from 48 per cent (tur) and (mung) to 50 per cent (gram). The minimum adult emergence in general (89 per cent) was recorded in tur and gram and maximum of 91 per cent in cowpea and mung.

The data pertaining to adult longevity was non-significant (Table 3). The adult longevity in males varied from 7.93 (tur) to 8.39 days (gram) and in females from 8.05 (cowpea) to 8.10 (tur) days. Longevity in general taking into consideration males and females together ranged from 8.01 days in tur to 8.23 days in gram.

The maximum sex ratio of male : female was recorded on gram (1:1.28) followed by tur (1:1.17), cowpea (1:1.16) and mung (1:1.11).

Table 3 : The mean adult emergence, longevity and sex ratio of *C. chinensis* on different pulses

Pulses	Per cent adult emergence			Adult longevity (days)			Sex ratio
	General	Male	Female	General	Male	Female	
Cowpea	91	42	49	8.17	8.29	8.05	1:1.16
Mung	91	43	48	8.16	8.26	8.06	1:1.11
Tur	89	41	48	8.01	7.93	8.10	1:1.17
Gram	89	39	50	8.23	8.39	8.07	1:1.28
S. E. ±	2.91	1.29	1.68	0.10	0.16	0.11	
C.D. at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	
C.V. (%)	9.94	10	11.36	2.96	4.55	3.17	

4.1.4 Life-cycle

The data in respect of pre-oviposition period, oviposition period and fecundity per female of *C. chinensis* on different pulses are presented in Table 4. The data (Table 4) revealed that the pre-oviposition period (hours), oviposition period (days) and fecundity per female were statistically non significant. Numerically highest pre-oviposition period (7.79 hours), oviposition period (8.46 days) and fecundity per female (80.40 eggs) were recorded on mung, cowpea and tur, respectively. The lowest pre-oviposition period of 7.42 hours, oviposition period of 8.21 days and fecundity of 77.40 eggs per female were recorded on gram, mung and cowpea, respectively.

Table 4 : The mean pre-oviposition and oviposition period and fecundity per female of *C. chinensis* on different pulses

Pulses	Pre-oviposition period (hours)	Oviposition period (days)	Fecundity / female
Cowpea	7.52	8.46	77.40
Mung	7.79	8.21	78.20
Tur	7.46	8.41	80.40
Gram	7.42	8.29	79.60
S. E. $\pm$	0.21	0.17	2.87
C.D. at 5%	N.S.	N.S.	N.S.
C.V. (%)	6.37	4.58	8.14

Cowpea

Mung

Tur

Gram

Eggs of *Callosobruchus chinensis* on different pulses

Male

Female

Adults

PLATE I: Life stages of *Callosobruchus chinensis* on different pulses

4.2 Life-fecundity tables of *C. chinensis* on different pulses

The life-fecundity tables of *C. chinensis* were constructed on four pulses viz., cowpea, mung, tur and gram. The observations were recorded on hatching of eggs, larval-pupal mortality, fecundity and age-specific mortality of females.

4.2.1 Life-fecundity tables of *C. chinensis* on cowpea

The data on the survival of life-stages of *C. chinensis* on cowpea are presented in Table 5.

The results showed that *C. chinensis* survived to the extent of 91 and 81 per cent in a cohort of 100 eggs. During the course of rearing from egg to adult emergence 36 per cent male and 45 per cent female beetles were emerged successfully.

Table 5 : Survival of life-stages of *C. chinensis* during development on cowpea

Number of eggs observed	Number surviving			
	Egg duration (0-5 days)	Larval-pupal duration (6-35 days)	Sex	
			Male	Female
20	19	17	08	09
20	18	15	07	08
20	18	16	06	10
20	18	17	08	09
20	18	16	07	09
100	91	81	36	45

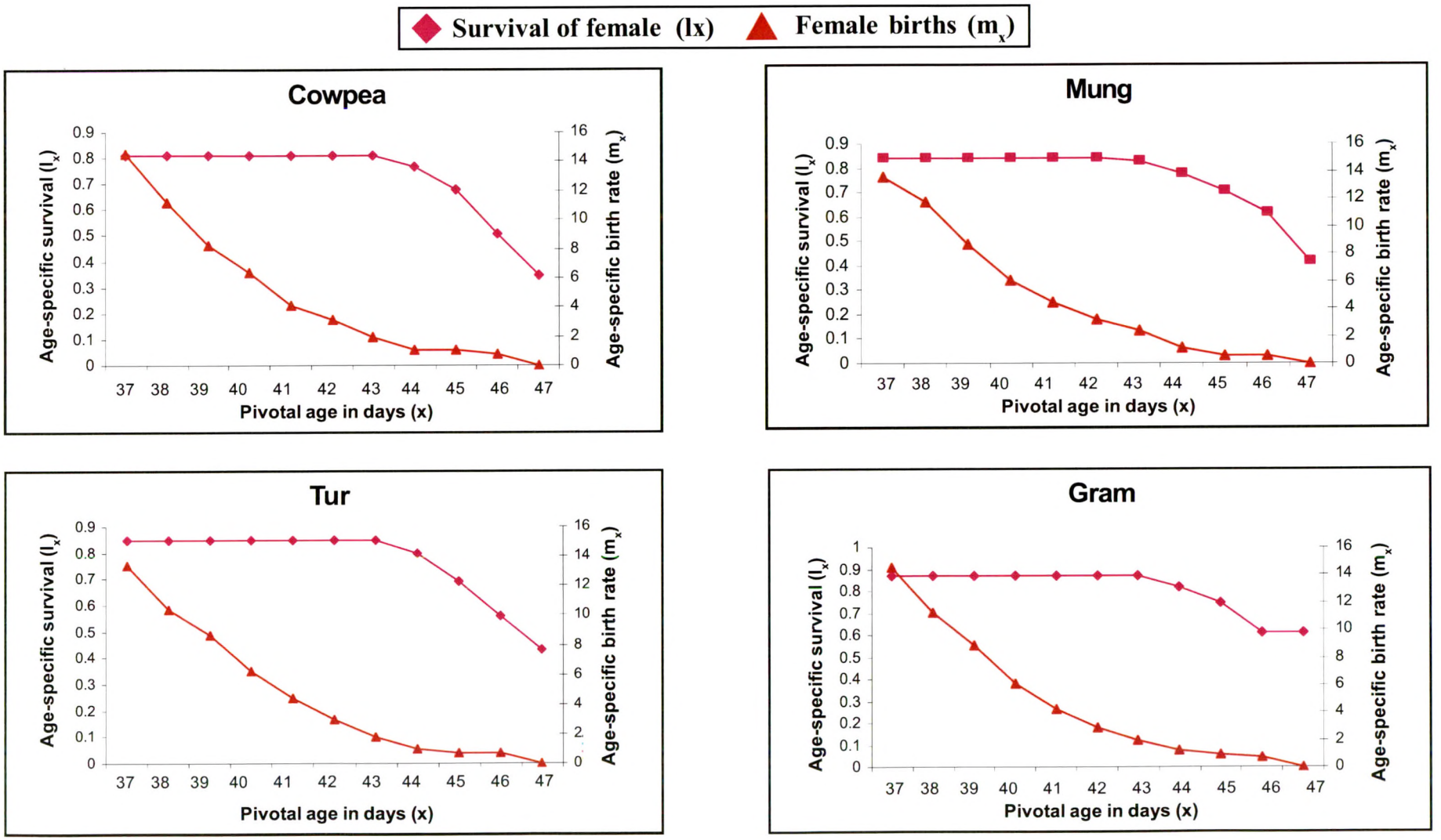


Fig. 1 Daily age - specific survival (l_x) and birth rate (m_x) of *C. chinensis* on different pulses

It is observed from Table 6 and Fig. 1 that the survival (l_x) was 0.81 per individual within a pivotal age of 35 days on cowpea. The number of eggs laid per female was divided by two to get the number of female births (m_x). The highest female births (11.74) was observed on first day of oviposition at 37th day of pivotal age. The female births thereafter decreased gradually. The female mortality was observed on 44th day (l_x = 0.77) of pivotal age. The net reproductive rate (R_0) representing the total females per female per generation was 42.07. Thus the population of *C. chinensis* was able to multiply 42.07 times per generation on cowpea.

Table 6 : Life-table and age-specific fecundity of *C. chinensis* on cowpea

Pivotal age in days	Survival of female at different age intervals	Age schedule for female births		
X	l_x	m_x	l_xm_x	l_xm_xX
0-35	0.81	Immature stages	-	-
36	0.81	Pre-oviposition period	-	-
37	0.81	14.50	11.74	434.38
38	0.81	11.22	9.09	345.42
39	0.81	8.21	6.65	259.35
40	0.81	6.35	5.14	205.6
41	0.81	4.13	3.34	136.94
42	0.81	3.12	2.53	106.26
43	0.81	1.93	1.56	67.08
44	0.77	1.12	0.86	37.84
45	0.68	1.10	0.75	33.75
46	0.51	0.80	0.41	18.86
47	0.35	0.00	0.00	0.00
			ΣI_xm_x= 42.07	ΣI_xm_xX= 1645.48

The results of mean length of generation and finite rate of increase in numbers of *C. chinensis* on cowpea are summarized in Table 7. The mean length of generation (T_c) was found to be 39.11 days, while innate capacity for increase in number (r_c) was 0.10 female per female per day. The corrected generation time (T) was 37.4 days, while the finite rate of increase in numbers (λ) was 1.10 females per female per day. The corrected innate capacity for increase in number (r_m) was 0.095 female per female per day.

Table 7 : Mean length of generation, innate capacity for increase in numbers and finite rate of increase in numbers of *C. chinensis* on cowpea

Population growth statistics	
Mean length of generation $T_c = \frac{\Sigma l_x m_x X}{R_0}$	39.11 days
Innate capacity for increase in numbers $r_c = \frac{\text{Log}_e R_o}{T_c}$	0.10 female/female/day
Arbitrary $r_m(r_c)$, 0.10, 0.11, 0.12	
Corrected r_m, $\Sigma e^{7-rmx} l_x m_x = 1096.6$	0.095 female/female/day
Corrected generation time $T = \frac{\text{Log}_e R_o}{r_m}$	37.40 days
Finite rate of increase in numbers (λ) $\lambda = \text{antilog}_e r_m$	1.10 Females/female/day

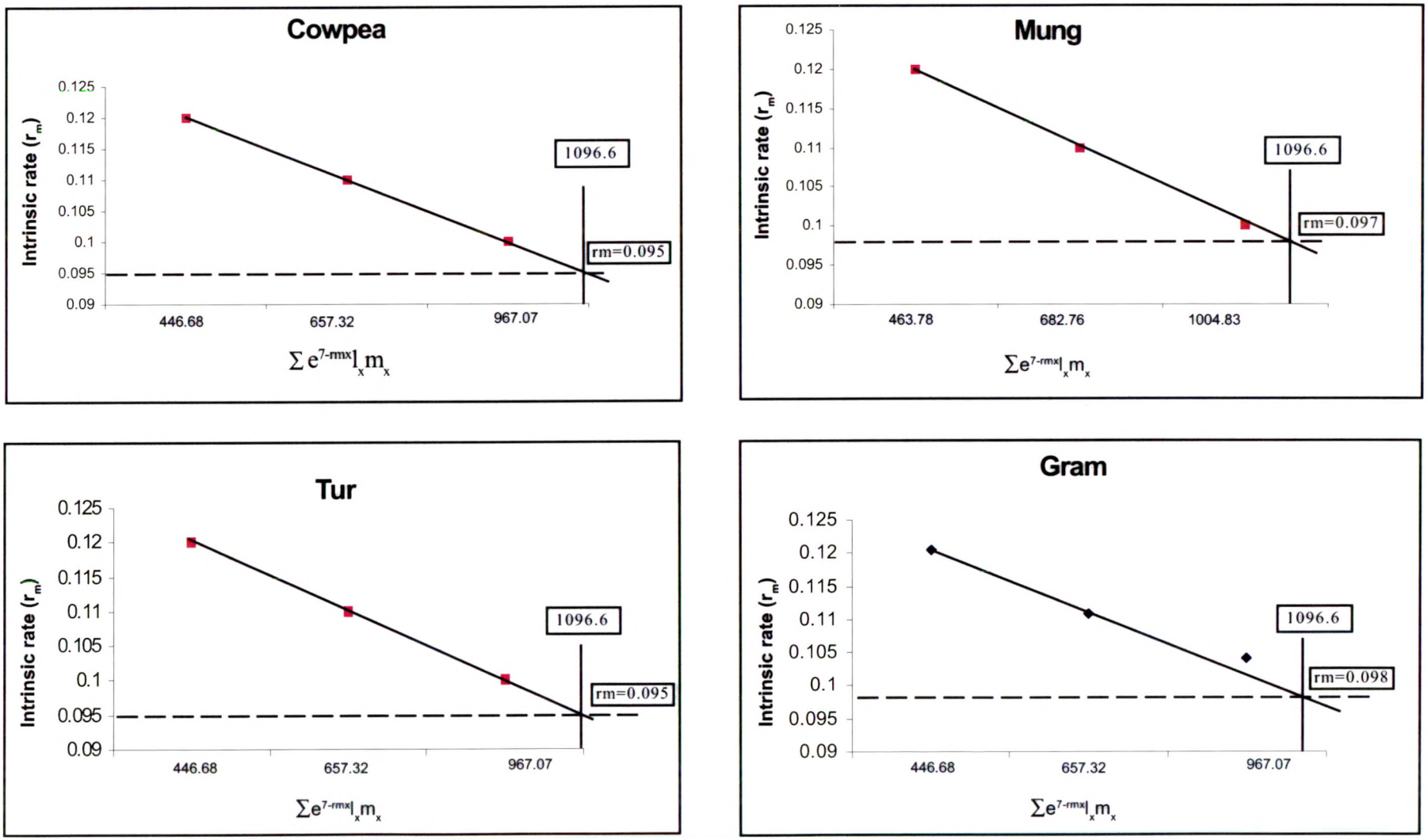
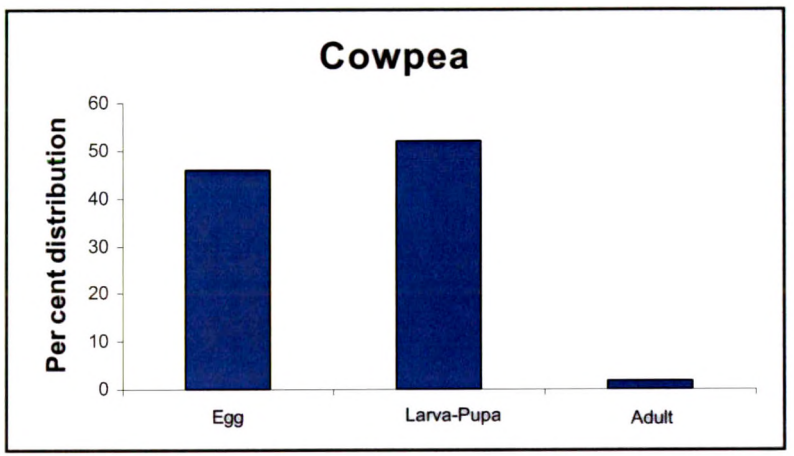


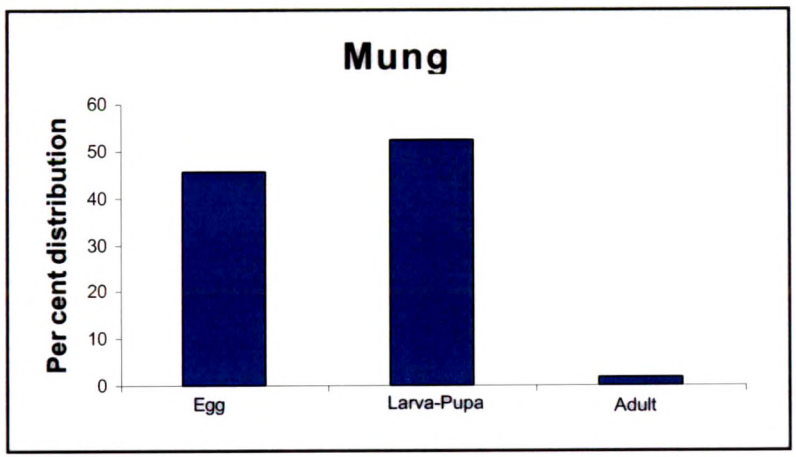
Fig. 2 : Determination of intrinsic rate of increase (r_m) of *C. chinensis* on different pulses.

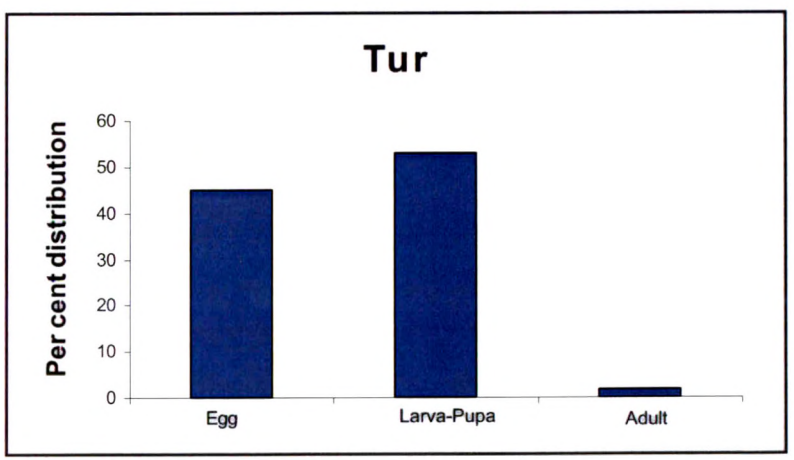
The three trial values (Table 8) of 967.07, 657.32 and 446.88 were plotted on horizontal axis against their respective arbitrary r_m (r_c) differing in second decimal place on either side of it i.e. 0.10, 0.11 and 0.12 on vertical axis and corrected r_m was calculated by interpolation method. Thus corrected r_m was calculated as 0.095 females per female per day (Fig. 2).

Table 8 : Calculation of r_m by trial and error method of *C. chinensis* on cowpea

Pivotal age	$l_x m_x$	$r_m = 0.10$		$r_m = 0.11$		$r_m = 0.12$	
		$e^{(7-rmx)}$	$e^{(7-rmx}$ $l_xm_x)$	$e^{(7-rmx)}$	$e^{(7-rmx}$ $l_xm_x)$	$e^{(7-rmx)}$	$e^{(7-rmx}$ $l_xm_x)$
36	0.81	29.96	24.27	20.90	16.93	14.58	11.81
37	11.74	27.11	318.27	18.73	219.89	12.93	151.80
38	9.09	24.53	222.98	16.78	152.53	11.47	104.26
39	6.65	22.20	147.63	15.03	99.95	10.17	67.63
40	5.14	20.08	103.21	13.46	69.18	9.02	46.36
41	3.34	18.17	60.69	12.06	40.28	8.00	26.72
42	2.53	16.44	41.59	10.80	27.32	7.10	17.96
43	1.56	14.88	23.21	9.68	15.10	6.30	9.83
44	0.86	13.46	11.57	8.67	7.46	5.58	4.80
45	0.75	12.18	9.13	7.77	5.83	4.95	3.71
46	0.41	11.02	4.52	6.96	2.85	4.39	1.80
47	0.00	9.97	0.00	6.23	0.00	3.90	0.00
Total			967.07		657.32		446.68







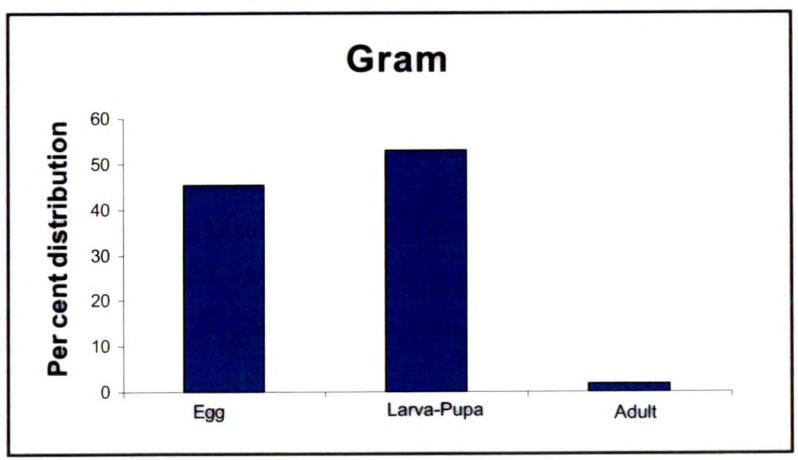


Fig. 3 Contribution of various life-stages towards stable age-distribution of *C.chinensis* on different pulses

The contribution made by different developmental stages towards stable age-distribution of *C. chinensis* on cowpea was determined and the data are presented in Table 9 and Fig. 3. It is observed from Table 9 that stable age distribution of population of *C. chinensis* on cowpea in egg, larval-pupal and adult stages distributed to the extent of 46.01, 52.19 and 1.80 per cent, respectively.

Table 9 : Stable age-distribution of *C. chinensis* on cowpea when $r_m = 0.095$

Age group in days (x)	Survival of individuals at different age intervals (l_x)	Stable age-distribution $L_x = \frac{l_x + (l_x + 1)}{2}$	$e^{-rm(x+1)}$	$L_x.e^{-rm(x+1)}$	Per cent distribution	
1	2	3	4	5	6	
0	1.00	1.00	0.9094	0.9094	9.7663	
1	1.00	1.00	0.8270	0.8270	8.8814	46.01
2	1.00	1.00	0.7520	0.7520	8.0759	Egg
3	1.00	1.00	0.6839	0.6839	7.3446	
4	1.00	0.96	0.6219	0.5970	6.4114	
5	0.91	0.91	0.5655	0.5146	5.5264	
6	0.91	0.91	0.5143	0.4680	5.0260	
7	0.91	0.91	0.4677	0.4256	4.5706	
8	0.91	0.91	0.4253	0.3870	4.1561	
9	0.91	0.91	0.3867	0.3519	3.7792	
10	0.91	0.91	0.3517	0.3200	3.4366	52.19
11	0.91	0.91	0.3198	0.2910	3.1251	Larval
12	0.91	0.91	0.2908	0.2646	2.8416	-pupal
13	0.91	0.91	0.2645	0.2407	2.5849	
14	0.91	0.91	0.2405	0.2189	2.3508	
15	0.91	0.91	0.2187	0.1990	2.1371	

1	2	3	4	5	6	
16	0.91	0.91	0.1989	0.1810	1.9438	
17	0.91	0.91	0.1809	0.1646	1.7677	
18	0.91	0.91	0.1645	0.1497	1.6077	
19	0.91	0.91	0.1496	0.1361	1.4616	
20	0.91	0.91	0.1360	0.1238	1.3295	
21	0.91	0.91	0.1237	0.1126	1.2092	
22	0.91	0.91	0.1125	0.1024	1.0997	
23	0.91	0.91	0.1023	0.0931	0.9998	
24	0.91	0.91	0.0930	0.0846	0.9085	
25	0.91	0.91	0.0846	0.0770	0.8269	
26	0.91	0.91	0.0769	0.0700	0.7518	
27	0.91	0.91	0.0699	0.0636	0.6830	
28	0.91	0.91	0.0636	0.0579	0.6218	
29	0.91	0.91	0.0578	0.0526	0.5649	
30	0.91	0.91	0.0526	0.0479	0.5144	
31	0.91	0.91	0.0478	0.0435	0.4672	
32	0.91	0.91	0.0435	0.0396	0.4253	
33	0.91	0.91	0.0396	0.0360	0.3866	
34	0.91	0.86	0.0360	0.0310	0.3329	
35	0.81	0.81	0.0327	0.0265	0.2846	
36	0.81	0.81	0.0297	0.0241	0.2588	
37	0.81	0.81	0.0271	0.0220	0.2363	
38	0.81	0.81	0.0246	0.0199	0.2137	
39	0.81	0.81	0.0224	0.0181	0.1944	
40	0.81	0.81	0.0203	0.0164	0.1761	
41	0.81	0.81	0.0185	0.0150	0.1611	1.80
42	0.81	0.81	0.0168	0.0136	0.1461	Adult
43	0.81	0.79	0.0153	0.0121	0.1299	
44	0.77	0.73	0.0139	0.0101	0.1085	
45	0.68	0.60	0.0127	0.0076	0.0816	
46	0.51	0.43	0.0115	0.0049	0.0526	
47	0.35	0.35	0.0105	0.0037	0.0397	

4.2.2 Life-fecundity tables of *C. chinensis* on mung

The data on the survival of life-stages of *C. chinensis* on mung are presented in Table 10.

Table 10 : Survival of life-stages of *C. chinensis* during development on mung

Number of eggs observed	Number surviving			
	Egg duration (0-5 days)	Larval-pupal duration (6-35 days)	Sex	
			Male	Female
20	19	18	09	09
20	19	17	08	09
20	18	16	08	08
20	19	16	07	09
20	20	17	08	09
100	95	84	40	44

It is observed that *C. chinensis* survived to the extent of 95 and 84 per cent in egg and larval-pupal stages in a cohort of 100 eggs. During the course of rearing from egg to adult emergence 40 and 44 per cent male and female beetles were emerged successfully.

It is evident from Table 11 and Fig. 1 that the survival (l_x) was 0.84 per individual within a pivotal age of 35 days on mung. The highest female births (13.55) was observed on first day of oviposition at 37th day of pivotal age. The female births thereafter decreased gradually. The first female mortality was observed on 43rd day of pivotal age. The net reproductive rate (R_o) representing the total females per female per generation was 43.83. Thus the population of *C. chinensis* was able to multiply 43.83 times per generation on mung.

Table 11 : Life-table and age-specific fecundity of *C. chinensis* on mung

Pivotal age in days	Survival of female at different age intervals	Age schedule for female births		
X	l_x	m_x	l_xm_x	l_xm_xX
0-35	0.84	Immature stages	-	-
36	0.84	Pre-oviposition period	-	-
37	0.84	13.55	11.38	421.06
38	0.84	11.81	9.92	376.96
39	0.84	8.65	7.27	283.53
40	0.84	6.09	5.11	204.4
41	0.84	4.49	3.77	154.57
42	0.84	3.24	2.72	114.24
43	0.83	2.37	1.97	84.71
44	0.78	1.13	0.88	38.72
45	0.71	0.62	0.44	19.80
46	0.62	0.60	0.37	17.02
47	0.42	0.00	0.00	0.00
			Σl_xm_x= 43.83	Σl_xm_xX= 1715.01

The results in respect of mean length of generation, intrinsic rate of increase in numbers of *C. chinensis* on mung are summarized in Table 12. The mean length of generation (T_c) was found to be 39.12 days. The arbitrary value for intrinsic rate of natural increase (r_c) was 0.10 female per female per day. The precise generation time (T) was 37.80 days. The finite rate of increase in numbers (λ) was 1.10 female per female per day.

Table 12 : Mean length of generation, innate capacity for increase in numbers and finite rate of increase in numbers of *C. chinensis* on mung

Population growth statistics	
Mean length of generation $T_c = \frac{\Sigma l_x m_x X}{R_0}$	39.12 days
Innate capacity for increase in numbers $r_c = \frac{\text{Log}_e R_o}{T_c}$	0.10 female/female/day
Arbitrary $r_m(r_c)$, 0.10, 0.11, 0.12	
Corrected r_m, $\Sigma e^{7-rmx} l_x m_x = 1096.6$	0.097 female/female/day
Corrected generation time $T = \frac{\text{Log}_e R_o}{r_m}$	37.80 days
Finite rate of increase in numbers (λ) $\lambda = \text{antilog}_e r_m$	1.10 Females/female/day

Three trial values (Table 13) of 1004.83, 682.76 and 463.78 were plotted on horizontal axis against their respective arbitrary (r_c) differing in second decimal place on either side of it i.e. 0.10, 0.11 and 0.12 on vertical axis and corrected (r_m) was calculated by interpolation method. Thus the corrected (r_m) was calculated as 0.097 female per female per day (Fig. 2).

Table 13 : Calculation of r_m by trial and error method of *C. chinensis* on mung

Pivotal age	$l_x m_x$	$r_m = 0.10$		$r_m = 0.11$		$r_m = 0.12$	
		$e^{(7-rmx)}$	$e^{(7-rmx)} l_x m_x$	$e^{(7-rmx)}$	$e^{(7-rmx)} l_x m_x$	$e^{(7-rmx)}$	$e^{(7-rmx)} l_x m_x$
36	0.84	29.96	25.17	20.90	17.56	14.58	12.25
37	11.38	27.11	308.51	18.73	213.15	12.93	147.14
38	9.92	24.53	243.34	16.78	166.46	11.47	113.78
39	7.27	22.20	161.39	15.03	109.27	10.17	73.93
40	5.11	20.08	102.61	13.46	68.78	9.02	46.09
41	3.77	18.17	68.50	12.06	45.47	8.00	30.16
42	2.72	16.44	44.72	10.80	29.38	7.10	19.31
43	1.97	14.88	29.31	9.68	19.07	6.30	12.41
44	0.88	13.46	11.84	8.67	7.63	5.58	4.91
45	0.44	12.18	5.36	7.77	3.42	4.95	2.18
46	0.37	11.02	4.08	6.96	2.57	4.39	1.62
47	0.00	9.97	0.00	6.23	0.00	3.90	0.00
Total			1004.83		682.76		463.78

The contribution made by different developmental stages towards stable age-distribution of *C. chinensis* on mung was determined and data are presented in Table 14 and Fig. 3. It is evident from Table 14 that the population of *C. chinensis* on mung in egg, larval-pupal and adult stages distributed to the extent of 45.77, 52.50 and 1.73 per cent, respectively.

Table 14 : Stable age-distribution of *C. chinensis* on mung when $r_m = 0.097$

Age group in days (x)	Survival of individuals at different age intervals (l_x)	Stable age-distribution $L_x = \frac{l_x + (l_x + 1)}{2}$	$e^{-rm(x+1)}$	$L_x.e^{-rm(x+1)}$	Per cent distribution	
1	2	3	4	5	6	
0	1.00	1.00	0.9076	0.9076	9.6803	
1	1.00	1.00	0.8237	0.8237	8.7855	45.77
2	1.00	1.00	0.7475	0.7475	7.9727	Egg
3	1.00	1.00	0.6784	0.6784	7.2357	
4	1.00	0.98	0.6157	0.6034	6.4358	
5	0.95	0.95	0.5588	0.5309	5.6625	
6	0.95	0.95	0.5071	0.4817	5.1377	
7	0.95	0.95	0.4602	0.4372	4.6631	
8	0.95	0.95	0.4177	0.3968	4.2322	
9	0.95	0.95	0.3791	0.3601	3.8408	
10	0.95	0.95	0.3440	0.3268	3.4856	52.50
11	0.95	0.95	0.3122	0.2966	3.1635	Larval
12	0.95	0.95	0.2834	0.2692	2.8713	-pupal
13	0.95	0.95	0.2572	0.2443	2.6057	
14	0.95	0.95	0.2334	0.2217	2.3646	
15	0.95	0.95	0.2118	0.2012	2.1460	
16	0.95	0.95	0.1922	0.1826	1.9476	
17	0.95	0.95	0.1745	0.1658	1.7684	
18	0.95	0.95	0.1583	0.1504	1.6041	
19	0.95	0.95	0.1437	0.1365	1.4559	
20	0.95	0.95	0.1304	0.1239	1.3215	

1	2	3	4	5	6	
21	0.95	0.95	0.1184	0.1125	1.1999	
22	0.95	0.95	0.1074	0.1020	1.0879	
23	0.95	0.95	0.0975	0.0926	0.9877	
24	0.95	0.95	0.0885	0.0841	0.8970	
25	0.95	0.95	0.0803	0.0763	0.8138	
26	0.95	0.95	0.0729	0.0693	0.7391	
27	0.95	0.95	0.0661	0.0628	0.6698	
28	0.95	0.95	0.0600	0.0570	0.6080	
29	0.95	0.95	0.0545	0.0518	0.5525	
30	0.95	0.95	0.0494	0.0469	0.5002	
31	0.95	0.95	0.0449	0.0427	0.4554	
32	0.95	0.95	0.0407	0.0387	0.4128	
33	0.95	0.95	0.0370	0.0352	0.3754	
34	0.95	0.90	0.0335	0.0302	0.3221	
35	0.84	0.84	0.0304	0.0255	0.2720	
36	0.84	0.84	0.0276	0.0232	0.2474	
37	0.84	0.84	0.0251	0.0211	0.2250	
38	0.84	0.84	0.0228	0.0192	0.2048	
39	0.84	0.84	0.0207	0.0174	0.1856	
40	0.84	0.84	0.0187	0.0157	0.1675	
41	0.84	0.84	0.0170	0.0143	0.1525	1.73
42	0.84	0.84	0.0154	0.0129	0.1376	Adult
43	0.83	0.81	0.0140	0.0113	0.1205	
44	0.78	0.75	0.0127	0.0095	0.1013	
45	0.71	0.67	0.0115	0.0077	0.0821	
46	0.62	0.52	0.0105	0.0055	0.0587	
47	0.42	0.42	0.0095	0.0040	0.0427	

4.2.3 Life-fecundity tables of *C. chinensis* on tur

The data on the survival of life stages of *C. chinensis* on tur are presented in Table 15.

It is revealed from the data presented in Table 15 that *C. chinensis* survived to the extent of 95 and 85 per cent in egg and larval-pupal stages in a cohort of 100 eggs. The emergence of male and female beetles was observed to be 41 and 44 per cent, respectively.

Table 15 : Survival of life-stages of *C. chinensis* during development on tur

Number of eggs observed	Number surviving			
	Egg duration (0-5 days)	Larval-pupal duration (6-35 days)	Sex	
			Male	Female
20	18	17	07	10
20	19	18	09	09
20	19	16	08	08
20	20	17	09	08
20	19	17	08	09
100	95	85	41	44

It is evident from Table 16 and Fig. 1 that the survival (l_x) was 0.85 per individual within a pivotal age of 35 days on tur. The highest female births (13.35) was observed on first day of oviposition at 37th day of pivotal age. Thereafter the female births were decreased. The female mortality was observed on 44th day of pivotal age. The net reproductive rate (R_0) representing the total females per female per generation was 42.49.

Table 16 : Life-table and age-specific fecundity of *C. chinensis* on tur

Pivotal age in days	Survival of female at different age intervals	Age schedule for female births		
X	l_x	m_x	l_xm_x	l_xm_xX
0-35	0.85	Immature stages	-	-
36	0.85	Pre-oviposition period	-	-
37	0.85	13.35	11.35	419.95
38	0.85	10.47	8.90	338.20
39	0.85	8.71	7.40	288.60
40	0.85	6.24	5.30	212.00
41	0.85	4.40	3.74	153.34
42	0.85	3.01	2.56	107.52
43	0.85	1.81	1.54	66.22
44	0.80	1.01	0.81	35.64
45	0.69	0.72	0.50	22.50
46	0.56	0.70	0.39	17.94
47	0.43	0.00	0.00	0.00
			ΣI_xm_x= 42.49	ΣI_xm_xX= 1661.91

The results in respect of mean length of generation, intrinsic rate of increase in number of *C. chinensis* on tur are summarized in Table 17. The mean length of generation (T_c) was found to be 39.11 days. The arbitrary value for intrinsic rate of natural increase (r_c) was 0.10 female per female per day. The precise generation time (T) was 37.5 days. The finite rate of increase in numbers (λ) was 1.11 females per female per day.

Table 17 : Mean length of generation, innate capacity for increase in numbers and finite rate of increase in numbers of *C. chinensis* on tur

Population growth statistics	
Mean length of generation $T_c = \frac{\Sigma l_x m_x X}{R_0}$	39.11 days
Innate capacity for increase in numbers $r_c = \frac{\text{Log}_e R_o}{T_c}$	0.10 female/female/day
Arbitrary $r_m(r_c)$, 0.10, 0.11, 0.12	
Corrected r_m, $\Sigma e^{7-rmx} l_x m_x = 1096.6$	0.095 female/female/day
Corrected generation time $T = \frac{\text{Log}_e R_o}{r_m}$	37.50 days
Finite rate of increase in numbers (λ) $\lambda = \text{antilog}_e r_m$	1.11 females/female/day

The three trial values (Table 18) of 976.42, 663.51 and 450.59 were plotted on horizontal axis against their respective arbitrary (r_c) differing in second decimal place on either side of it i.e. 0.10, 0.11 and 0.12 on vertical axis and corrected (r_m) was calculated by interpolation method. The corrected r_m was calculated as 0.095 females per female per day (Fig. 3).

Table 18 : Calculation of r_m by trial and error method of *C. chinensis* on tur

Pivotal age	$l_x m_x$	$r_m = 0.10$		$r_m = 0.11$		$r_m = 0.12$	
		$e^{(7-rmx)}$	$e^{(7-rmx}$ $l_xm_x)$	$e^{(7-rmx)}$	$e^{(7-rmx}$ $l_xm_x)$	$e^{(7-rmx)}$	$e^{(7-rmx}$ $l_xm_x)$
36	0.85	29.96	25.47	20.90	17.76	14.58	12.39
37	11.35	27.11	307.70	18.73	212.58	12.93	146.75
38	8.90	24.53	218.31	16.78	149.34	11.47	102.08
39	7.40	22.20	164.28	15.03	111.22	10.17	75.26
40	5.30	20.08	106.42	13.46	71.34	9.02	47.81
41	3.74	18.17	67.95	12.06	45.10	8.00	29.92
42	2.56	16.44	42.09	10.80	27.65	7.10	18.18
43	1.54	14.88	22.91	9.68	14.91	6.30	9.70
44	0.81	13.46	10.90	8.67	7.02	5.58	4.52
45	0.50	12.18	6.09	7.77	3.88	4.95	2.47
46	0.39	11.02	4.30	6.96	2.71	4.39	1.71
47	0.00	9.97	0.00	6.23	0.00	3.90	0.00
Total			976.42		663.51		450.79

The contribution made by different developmental stages towards stable age-distribution of *C. chinensis* on tur was determined and data are presented in Table 19 and Fig. 3. It is observed that population of *C. chinensis* on tur in egg, larval-pupal and adult stages distributed to the extent of 45.13, 53.02 and 1.85 per cent, respectively.

Table 19 : Stable age-distribution of *C. chinensis* on tur when $r_m = 0.095$

Age group in days (x)	Survival of individuals at different age intervals (l_x)	Stable age-distribution $L_x = \frac{l_x + (l_x + 1)}{2}$	$e^{-rm(x+1)}$	$L_x.e^{-rm(x+1)}$	Per cent distribution	
1	2	3	4	5	6	
0	1.00	1.00	0.9094	0.9094	9.5025	
1	1.00	1.00	0.8270	0.8270	8.6415	45.13
2	1.00	1.00	0.7520	0.7520	7.8578	Egg
3	1.00	1.00	0.6839	0.6839	7.1462	
4	1.00	0.98	0.6219	0.6095	6.3688	
5	0.95	0.95	0.5655	0.5372	5.6133	
6	0.95	0.95	0.5143	0.4886	5.1055	
7	0.95	0.95	0.4677	0.4443	4.6426	
8	0.95	0.95	0.4253	0.4040	4.2215	
9	0.95	0.95	0.3867	0.3674	3.8390	
10	0.95	0.95	0.3517	0.3341	3.4911	53.02
11	0.95	0.95	0.3198	0.3038	3.1745	Larval
12	0.95	0.95	0.2908	0.2763	2.8871	-pupal
13	0.95	0.95	0.2645	0.2513	2.6259	
14	0.95	0.95	0.2405	0.2285	2.3876	
15	0.95	0.95	0.2187	0.2078	2.1713	
16	0.95	0.95	0.1989	0.1890	1.9749	
17	0.95	0.95	0.1809	0.1719	1.7962	
18	0.95	0.95	0.1645	0.1563	1.6332	
19	0.95	0.95	0.1496	0.1421	1.4848	
20	0.95	0.95	0.1360	0.1292	1.3500	
21	0.95	0.95	0.1237	0.1175	1.2278	

1	2	3	4	5	6	
22	0.95	0.95	0.1125	0.1069	1.1170	
23	0.95	0.95	0.1023	0.0972	1.0157	
24	0.95	0.95	0.0930	0.0884	0.9237	
25	0.95	0.95	0.0846	0.0804	0.8401	
26	0.95	0.95	0.0769	0.0731	0.7638	
27	0.95	0.95	0.0699	0.0664	0.6938	
28	0.95	0.95	0.0636	0.0604	0.6311	
29	0.95	0.95	0.0578	0.0549	0.5737	
30	0.95	0.95	0.0526	0.0500	0.5225	
31	0.95	0.95	0.0478	0.0454	0.4744	
32	0.95	0.95	0.0435	0.0413	0.4316	
33	0.95	0.95	0.0396	0.0376	0.3929	
34	0.95	0.90	0.0360	0.0324	0.3386	
35	0.85	0.85	0.0327	0.0278	0.2905	
36	0.85	0.85	0.0297	0.0252	0.2633	
37	0.85	0.85	0.0271	0.0230	0.2403	
38	0.85	0.85	0.0246	0.0209	0.2184	
39	0.85	0.85	0.0224	0.0190	0.1985	
40	0.85	0.85	0.0203	0.0173	0.1808	
41	0.85	0.85	0.0185	0.0157	0.1641	1.85
42	0.85	0.85	0.0168	0.0143	0.1494	Adult
43	0.85	0.83	0.0153	0.0127	0.1327	
44	0.80	0.75	0.0139	0.0104	0.1087	
45	0.69	0.63	0.0127	0.0080	0.0836	
46	0.56	0.50	0.0115	0.0058	0.0606	
47	0.43	0.43	0.0105	0.0045	0.0470	

4.2.4 Life-fecundity tables of *C. chinensis* on gram

The data on the survival of life-stages of *C. chinensis* on gram are presented in Table 20.

Table 20 : Survival of life-stages of *C. chinensis* during development on gram

Number of eggs observed	Number surviving			
	Egg duration (0-5 days)	Larval-pupal duration (6-35 days)	Sex	
			Male	Female
20	20	17	09	08
20	19	18	08	10
20	20	18	10	08
20	19	15	07	08
20	20	19	09	10
100	98	87	43	44

It is observed that *C. chinensis* survived to the extent of 98 and 87 per cent in egg and larval-pupal stages in a cohort of 100 eggs. During the course of rearing from egg to adult emergence 43 and 44 per cent male and female beetles were emerged.

It is evident from Table 21 and Fig. 1 that the survival (l_x) was 0.87 per individual within a pivotal age of 35 days on gram. The highest female births (14.60) was observed on first day of oviposition on 37th day of pivotal age. Thereafter the female births were decreased gradually. The female mortality was observed on 44th day of the pivotal age. The net reproductive rate (R_0) was 45.5 females per female per generation.

Table 21 : Life-table and age-specific fecundity of *C. chinensis* on gram

Pivotal age in days	Survival of female at different age intervals	Age schedule for female births		
X	l_x	m_x	l_xm_x	l_xm_xX
0-35	0.87	Immature stages	-	-
36	0.87	Pre-oviposition period	-	-
37	0.87	14.60	12.70	469.90
38	0.87	11.25	9.79	372.02
39	0.87	8.85	7.70	300.30
40	0.87	6.08	5.29	211.60
41	0.87	4.22	3.67	150.47
42	0.87	2.87	2.50	105.00
43	0.87	1.95	1.70	73.10
44	0.82	1.25	1.02	44.88
45	0.75	0.93	0.70	31.50
46	0.61	0.71	0.43	19.78
47	0.47	0.00	0.00	0.00
			Σl_xm_x= 45.50	Σl_xm_xX= 1778.55

The results in respect of mean length of generation, intrinsic rate of increase in number of *C. chinensis* on gram are summarized in Table 22. The mean generation length (T_c) was found to be 39.09 days. The arbitrary value for intrinsic rate of natural increase (r_c) was 0.098 female per female per day. The precise generation time (T) was 38.2 days. The finite rate of increase in numbers (λ) was 1.11 females per female per day.

Table 22 : Mean length of generation, innate capacity for increase in numbers and finite rate of increase in numbers of *C. chinensis* on gram

Population growth statistics	
Mean length of generation	
$T_c = \frac{\Sigma l_x m_x X}{R_0}$	39.09 days
Innate capacity for increase in numbers	
$r_c = \frac{\text{Log}_e R_o}{T_c}$	0.10 female/female/day
Arbitrary $r_m(r_c)$, 0.10, 0.11, 0.12	
Corrected r_m, $\Sigma e^{7-rmx} l_x m_x = 1096.6$	0.098 female/female/day
Corrected generation time	
$T = \frac{\text{Log}_e R_o}{r_m}$	38.20 days
Finite rate of increase in numbers (λ)	
$\lambda = \text{antilog}_e r_m$	1.11 females/female/day

The three trial values (Table 23) of 1047.75, 712.25 and 484.06 were plotted on horizontal axis against their respective arbitrary (r_c) differing in second decimal place on either side of it i.e. 0.10, 0.11 and 0.12 on vertical axis and corrected (r_m) was calculated by interpolation method. The corrected r_m was calculated as 0.098 female per female per day (Fig. 2).

Table 23 : Calculation of r_m by trial and error method of *C. chinensis* on gram

Pivotal age	$l_x m_x$	$r_m = 0.10$		$r_m = 0.11$		$r_m = 0.12$	
		$e^{(7-rmx)}$	$e^{(7-rmx}$ $l_xm_x)$	$e^{(7-rmx)}$	$e^{(7-rmx}$ $l_xm_x)$	$e^{(7-rmx)}$	$e^{(7-rmx}$ $l_xm_x)$
36	0.87	29.96	26.06	20.90	18.18	14.58	12.68
37	12.70	27.11	344.30	18.73	237.87	12.93	164.21
38	9.79	24.53	240.15	16.78	164.28	11.47	112.29
39	7.70	22.20	170.94	15.03	115.73	10.17	78.31
40	5.29	20.08	106.22	13.46	71.20	9.02	47.71
41	3.67	18.17	66.68	12.06	44.26	8.00	29.36
42	2.50	16.44	41.10	10.80	27.00	7.10	17.75
43	1.70	14.88	25.30	9.68	16.46	6.30	10.71
44	1.02	13.46	13.73	8.67	8.84	5.58	5.69
45	0.70	12.18	8.53	7.77	5.44	4.95	3.46
46	0.43	11.02	4.74	6.96	2.99	4.39	1.89
47	0.00	9.97	0.00	6.23	0.00	3.90	0.00
Total			1047.75		712.25		484.06

The contribution made by different developmental stages towards stable age-distribution of *C. chinensis* on gram was determined and data are presented in Table 24 and Fig. 3. It is observed that population of *C. chinensis* on gram in egg, larval-pupal and adult stages distributed to the extent of 45.44, 52.85 and 1.71 per cent, respectively.

Table 24 : Stable age-distribution of *C. chinensis* on gram when $r_m = 0.098$

Age group in days (x)	Survival of individuals at different age intervals (l_x)	Stable age-distribution $L_x = \frac{l_x + (l_x + 1)}{2}$	$e^{-rm(x+1)}$	$L_x.e^{-rm(x+1)}$	Per cent distribution	
1	2	3	4	5	6	
0	1.00	1.00	0.9066	0.9066	9.5796	
1	1.00	1.00	0.8220	0.8220	8.6856	45.44
2	1.00	1.00	0.7452	0.7452	7.8741	Egg
3	1.00	1.00	0.6757	0.6757	7.1398	
4	1.00	0.99	0.6126	0.6064	6.4075	
5	0.98	0.98	0.5554	0.5443	5.7513	
6	0.98	0.98	0.5036	0.4935	5.2146	
7	0.98	0.98	0.4566	0.4475	4.7285	
8	0.98	0.98	0.4140	0.4057	4.2868	
9	0.98	0.98	0.3753	0.3678	3.8863	
10	0.98	0.98	0.3403	0.3335	3.5239	52.85
11	0.98	0.98	0.3085	0.3023	3.1942	Larval
12	0.98	0.98	0.2797	0.2741	2.8963	-pupal
13	0.98	0.98	0.2536	0.2485	2.6258	
14	0.98	0.98	0.2299	0.2253	2.3806	
15	0.98	0.98	0.2085	0.2043	2.1587	
16	0.98	0.98	0.1890	0.1852	1.9569	
17	0.98	0.98	0.1714	0.1680	1.7752	
18	0.98	0.98	0.1554	0.1523	1.6093	
19	0.98	0.98	0.1409	0.1381	1.4592	
20	0.98	0.98	0.1277	0.1251	1.3219	
21	0.98	0.98	0.1158	0.1135	1.1993	

1	2	3	4	5	6	
22	0.98	0.98	0.1050	0.1029	1.0873	
23	0.98	0.98	0.0952	0.0932	0.9848	
24	0.98	0.98	0.0863	0.0846	0.8939	
25	0.98	0.98	0.0782	0.0766	0.8094	
26	0.98	0.98	0.0709	0.0694	0.7333	
27	0.98	0.98	0.0643	0.0630	0.6657	
28	0.98	0.98	0.0583	0.0571	0.6033	
29	0.98	0.98	0.0529	0.0518	0.5473	
30	0.98	0.98	0.0479	0.0469	0.4956	
31	0.98	0.98	0.0435	0.0426	0.4501	
32	0.98	0.98	0.0394	0.0386	0.4079	
33	0.98	0.98	0.0357	0.0350	0.3698	
34	0.98	0.93	0.0324	0.0301	0.3181	
35	0.87	0.87	0.0294	0.0256	0.2705	
36	0.87	0.87	0.0266	0.0231	0.2441	
37	0.87	0.87	0.0241	0.0210	0.2219	
38	0.87	0.87	0.0219	0.0191	0.2018	
39	0.87	0.87	0.0198	0.0172	0.1817	
40	0.87	0.87	0.0180	0.0157	0.1659	
41	0.87	0.87	0.0163	0.0142	0.1500	1.71
42	0.87	0.87	0.0148	0.0129	0.1363	Adult
43	0.87	0.85	0.0134	0.0114	0.1205	
44	0.82	0.79	0.0122	0.0096	0.1014	
45	0.75	0.68	0.0110	0.0075	0.0792	
46	0.61	0.54	0.0100	0.0054	0.0571	
47	0.47	0.47	0.0091	0.0043	0.0454	

DISCUSSION

Chapter V

DISCUSSION

The results obtained in the present investigations on biology and life-fecundity tables of *C. chinensis* (Linn.) on different pulses are discussed in this chapter in the light of available literature under the following headings.

5.1 Biology of *C. chinensis* on different pulses

5.2 Life-fecundity tables of *C. chinensis* on different pulses

5.3 Overall suitability of pulses

5.1 Biology

The highest incubation period of *C. chinensis* was recorded on cowpea (4.43 days) followed by gram (4.31 days), mung (4.21 days) and tur (4.18 days).

Raina (1970) observed that average incubation period of *C. chinensis* was 3 to 5 days at 30^0C and 90 per cent relative humidity on mung bean. Pandey and Singh (1997) also found 4 to 5 days incubation period of *C. chinensis* on urd (*Vigna mungo*) and chickpea (*Cicer arietinum*) seeds. Singh and Rina Kumari (2000) reported the incubation period of *C. chinensis* on cowpea and gram to the tune of 4 to 5 days at 28 ± 2^0C temperature and 70-75 per cent relative humidity. Bhargava *et al.* (2008) reported 4.40 days incubation period of *C. chinensis* on copwea and 7.20 days on soybean.

The egg hatching of *C. chinensis* was found to be 95.00 to 98.00 per cent on different pulses. The maximum egg hatching was observed on gram (98.00 per cent) and minimum on cowpea (95.00 per cent).

Raina (1970) observed egg hatching of *C. chinensis* ranging from 94 to 99 per cent on mung bean. Gill and Ramzan (1998) also noted egg hatching of *C. maculatus* to the tune of 93.1 per cent on green gram.

The minimum larval-pupal period of 18.98 days was observed on gram and maximum of 26.60 days on cowpea. Raina (1970) reported the combined larval and pupal period of *C. chinensis* to the extent of 18.8 days on mung bean. Pandey and Singh (1997) found combined larval-pupal period of *C. chinensis* to the tune of 20 to 28 days on urd and chickpea. Singh and Rina Kumari (2000) also reported 20 days larval-pupal period of *C. chinensis* on cowpea and gram at room temperature. Bhargava *et al.* (2008) reported the mean larval and pupal period ranging from 14.80 to 26.20 days and 5.40 to 11.40 days on different pulses.

The highest growth index was observed when *C. chinensis* was reared on gram (2.72) and lowest on mung (2.68). Singh *et al.* (1980) noted the growth index of *C. chinensis* from 2.67 to 5.15 on different pulses including cowpea. Manohar and Yadav (1990) reported the growth index of the *C. chinensis* ranging from 2.54 to 4.11 on different pulses including cowpea. Bhargava *et al.* (2008) observed the minimum growth index on soybean (1.71) followed by pea (2.08), pigeonpea (2.16), gram (2.39), moth (2.38) and mung (3.06), while it was maximum on cowpea (3.51).

The significantly lowest life-cycle duration of *C. chinensis* was recorded for male (23.10 days), female (23.48 days) and in general (23.29 days) when reared on gram grains. The significantly longer life-cycle of female (30.70 days) and in general (30.49 days) *C. chinensis* was observed on tur. Kim and Choi (1987) reported that the developmental

period of *C. chinensis* was 29 days on azuki bean (*Vigna angularis*) and 31 days on mung bean (*Vigna radiata*) at 25^{0}C. Singal (1998) found *C. chinensis* completed it's life-cycle from egg laying to adult emergence in an average period of 34.5 days in field and 35.5 days under laboratory conditions. Bhargava *et al.* (2008) reported the developmental period of *C. chinensis* from 24.60 to 44.80 days on different pulses including cowpea, mung, moth, gram, pigeonpea, pea and soybean.

The data pertaining to per cent adult emergence and adult longevity was statistically non significant. The adult emergence of *C. chinensis* was higher in cowpea and mung (91 per cent). The adult longevity was highest on gram (8.23 days). Jadhav *et al.* (1984) recorded the adult emergence of *C. maculatus* ranging from 20.83 to 50.29 per cent when reared on chickpea. Manohar and Yadav (1990) reported the adult emergence of *C. chinensis* to the extent of 72.00 to 96.00 per cent on cowpea. Bhargava *et al.* (2008) observed the adult emergence of 76.45 per cent on soybean and 86.27 per cent on cowpea.

As regards the adult longevity Ahmed *et al.* (1978) observed male and female life-span of 7.10 and 6.70 days, respectively in *C. maculatus*. Singal and Borah (2001) reported that an average longevity of male and female was 6.2 $\pm$ 0.36 and 6.8 $\pm$ 0.25 days, respectively. Bhargava *et al.* (2008) noted the longevity of male and female beetles ranging from 6.20 to 8.80 and 5.60 to 8.40 days, respectively being minimum in soybean and maximum on cowpea in both the sexes. However, Dhepe *et al.* (1993) and Singh and Pandey (1994) reported that the longevity of both sexes of *C. chinensis* was not significantly affected by different varieties of green gram and gram, respectively.

Numerically highest pre-oviposition period (7.79 hours), oviposition period (8.46 days) and fecundity per female (80.40 eggs) were recorded on mung, cowpea and tur, respectively. According to Rajak and Pandey (1965) a female of *C. chinensis* laid 50 to 103 eggs in her life time. Raina (1970) noted that *C. chinensis* female laid an average of 78 eggs with a range of 63 to 90 over a period of eight days. Khare (1994) reported the egg laying of *C. chinensis* in between 60 and 90 eggs. An average of 70 eggs were laid by female *C. chinensis* when grown on urd and chickpea (Pandey and Singh, 1997) and cowpea and gram (Singh and Rina Kumari (2000). Singal and Borah (2001) reported that the average pre-oviposition period of *C. chinensis* lasted for 7.8 $\pm$ 0.46 hours on pods of *Cajanus cajan*. Bhargava *et al.* (2008) observed maximum of 70.20 eggs on mung followed by pigeonpea (69.80), gram (69.40), moth (66.40) and pea (60.00). However, the minimum number of eggs (47.40) was laid on soybean.

The sex ratio of male: female was 1:1.16 on cowpea, 1:1.11 on mung, 1:1.17 on tur and 1:1.28 on gram. Gokhale (1973) recorded sex ratio of *C. maculatus* (1:0.93 and 1:1) when reared on chickpea and Bengal gram, respectively. Begum *et al.* (1979) observed sex ratio of *C. chinensis* (1:1) when reared on mung, gram and pea. Manohar and Yadav (1990) recorded sex ratio of *C. maculatus* ranging from 1:0.93 to 1:1.40 when reared on different cowpea varieties.

5.2 Life-fecundity tables

The survival of immature stages (l_x) of *C. chinensis* was 0.81, 0.84, 0.85 and 0.87 per individual within a pivotal age of 35 days on cowpea, mung, tur and gram, respectively. The net reproductive rate (R_0)

of *C. chinensis* was 42.07, 43.83, 42.49 and 45.50 females per female per generation on cowpea, mung, tur and gram, respectively.

The mean length of generation time (T) was differed considerably on different pulses. It was maximum on gram (38.20 days) and minimum on cowpea (37.40 days). Borikar and Pawar (1996) reported that the mean time for completion of generation by *C. chinensis* on mung bean was 30.51 days. The innate capacity for increase in numbers (r_m) ranged from 0.095 to 0.098. On the basis of 'r_m' values the descending order of pulses for *C. chinensis* was gram (0.098), mung (0.097), tur (0.095) and cowpea (0.095). The finite rate of increase in numbers (λ) was 1.11, 1.11, 1.10 and 1.10 females per female per day on gram, tur, mung and cowpea, respectively.

Borikar and Pawar (1996) studied the life-fecundity tables of *C. chinensis* on mung bean and found that the population of *C. chinensis* increased with the innate capacity for increase in numbers (r_m) 0.08 and finite rate of increase in number (λ) 1.80 per day. The distribution of egg stage in the stable age-distribution was 46.01, 45.77, 45.13 and 45.44 per cent on cowpea, mung, tur and gram, respectively. The corresponding values for larval-pupal stage were 52.19, 52.50, 53.02 and 52.85 per cent.

Borikar and Pawar (1996) observed that *C. chinensis* on reaching the stable age-distribution, the population at various stages of egg, larva-pupa and adult accounted for 46.11, 51.16 and 2.71 per cent respectively.

On the basis of net reproductive rate (R_0), innate capacity for increase in number (r_m), gram occupied first position followed by mung, tur and cowpea.

5.3 Overall suitability of pulses

The studies on biology and life-fecundity tables of *C. chinensis* on different pulses were considered togetherly in order to understand the overall order of suitability of different pulses for *C. chinensis*. The pulses were arranged for each characters and scored by giving ten points for first position and reducing the one point for each subsequent position. The total score for each pulses was considered in arranging them in the order of suitability. The varieties were arranged in ascending order for characters like larval-pupal duration, life-cycle, pre-oviposition, generation time (T) and pivotal age for immature stages, while for the characters like growth index, per cent adult emergence, oviposition, fecundity, survival of immature stage (l_x), net reproductive rate (R_0) and innate capacity for increase in numbers (r_m) they were arranged in descending order (Appendix-I).

Thus, the overall order of suitability of different pulses in descending order with respective total points obtained was gram (113), tur (105), mung (101) and cowpea (96).

SUMMARY

Chapter VI

SUMMARY

The life-fecundity tables of *C. chinensis* were studied on different pulses during monsoon, 2006-2007 at the Department of Agricultural Entomology, College of Agriculture, Latur. The results obtained during the course of investigation are summarized as follows.

6.1 The mean incubation period of *C. chinensis* on different pulses varied from 4.18 to 4.43 days. The highest egg hatching was observed on gram (98.00 per cent), while lowest egg hatching was observed on cowpea and tur (95.00 per cent). The shortest mean larval-pupal duration (18.98 days) and highest growth index (2.72) of *C. chinensis* were recorded on gram. The significantly highest life-cycle duration of male, female and in general (30.28, 30.70 and 30.49 days) was observed on tur and lowest on gram (23.10, 23.48 and 23.29), respectively. The lowest adult emergence (89.00) was observed on tur and gram. The highest adult longevity in general was observed on gram (8.23 days).

The lowest pre-oviposition period (7.42 hours) and highest oviposition period (8.46 days) was observed on gram and cowpea, respectively. The highest number of eggs were laid by the female beetles that emerged from those larvae which were reared on tur (80.40), followed by gram (79.60), mung (78.20) and and cowpea (77.40).

6.2 The net reproductive rate (R_0) of *C. chinensis* was 42.07, 43.83, 42.49 and 45.50 females per female per generation on cowpea, mung, tur and gram, respectively. The mean length of generation (T) was maximum (38.80 days) on gram and minimum (37.40 days) on cowpea. On the basis of (r_m) values the descending order of food grains

for *C. chinensis* was gram (0.098), mung (0.097), tur (0.095) and cowpea (0.095). The finite rate of increase in numbers (λ) was 1.10, 1.10, 1.11 and 1.11 females per female per day on cowpea, mung, tur and gram, respectively. The distribution of egg stage in the stable age-distribution was 46.01, 45.77, 45.13 and 45.44 per cent on cowpea, mung, tur and gram, respectively. The corresponding values for larval-pupal distribution were 52.19, 52.50, 53.02 and 52.85 per cent.

6.3 The overall order of suitability of different pulses in descending order with respective total points obtained was gram (113), tur (105), mung (101) and cowpea (96). This indicated that gram was found to be most suitable for growth and multiplication of *C. chinensis* while, cowpea was observed to be less suitable for the development of pulse beetle *C. chinensis*.

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*Originals not seen

APPENDIX

APPENDIX – I

Relative order of different parameters for growth and development of *C. chinensis* on different pulses.

Sr. No.	Character	Score			
		Cowpea	Mung	Tur	Gram
1.	Larval-pupal duration	07	09	08	10
2.	Growth index	09	08	09	10
3.	Percent adult emergence	10	10	09	09
4.	Life-cycle duration	09	08	07	10
5.	Pre-oviposition	08	07	09	10
6.	Oviposition	10	07	09	08
7.	Fecundity	07	08	10	09
8.	Pivotal age for immature stages (x)	10	10	10	10
9.	Survival of immature stages (l_x)	07	09	08	10
10.	Net reproductive rate (R_0)	07	09	08	10
11.	Innate capacity for increase in numbers (r_m)	09	08	09	10
12.	Precise generation time (T)	10	08	09	07
	Total	96	101	105	113

APPENDIX II

Weekwise meteorological data during the period of investigation

Year	:	2006-07	Latitude	:	18^0 24'N
State	:	Maharashtra	Longitude	:	76^0 36'
District	:	Latur	Altitude	:	633.85 m.
Locations			Soil type	:	Vertisol

Month	Met. week No	Temp. (^{0}C)		Relative humidity		Rainfall (mm)	Number of rainy days
		Mean Max.	Mean Min.	Max. (%)	Min. (%)		
1	2	3	4	5	6	7	8
Aug. 06	32	28.2	16.9	140	4	84.1	75.0
	33	29.5	20.6	11.8	1	80.0	74.4
	34	30.2	20.7	0.2	0	84.2	74.8
	35	31.7	20.2	--	--	83.8	74.7
Sept. 06	36	32.0	21.0	73.6	3	77.1	76.7
	37	30.3	21.7	21.0	2	89.5	86.8
	38	28.5	22.0	117	3	85.2	80.4
	39	30.5	21.0	22.2	1	85.7	71.5
Oct. 06	40	30.7	20.2	51.3	3	86.8	71.8
	41	30.6	20.7	--	--	84.5	72.1
	42	31.5	18.8	--	--	72.5	68.4
	43	31.5	20.1	--	--	77.4	78.0
	44	32.0	17.5	--	--	84.1	79.2
Nov. 06	45	30.5	14.2	--	--	71.0	74.4
	46	29.5	13.5	--	--	73.8	73.1
	47	29.8	14.0	6	1	69.1	72.0
	48	30.6	16.0	--	--	76.4	67.2
Dec. 06	49	30.4	13.4	--	--	68.0	76.0
	50	30.3	12.2	--	--	69.7	64.8
	51	29.0	9.8	--	--	72.0	65.4
	52	29.4	12.1	--	--		69.5