GROWTH AND DEVELOPMENT OF *Achaea janata* ON DIFFERENT VARIETIES OF CASTOR

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B.Sc. (Agri.)

MASTER OF SCIENCE
(Agriculture)
IN
AGRICULTURAL ENTOMOLOGY

DEPARTMENT OF ENTOMOLOGY
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DISSERTATION

Submitted to
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DEPARTMENT OF ENTOMOLOGY
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MARATHWADA AGRICULTURAL UNIVERSITY,
PARBHANI

2005

Dedicated to

My Beloved

Parents

Brothers and

Sisters

CANDIDATE'S DECLARATION

I hereby declare that the dissertation

or part thereof, has not been

previously submitted by

me for a degree of

any University.

Madhavi

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CERTIFICATE – II

This is to certify that the dissertation entitled **"GROWTH AND DEVELOPMENT OF *Achaea janata* ON DIFFERENT VARIETIES OF CASTOR"** submitted by Miss. **KARAD MADHAVI LAXUMANRAO** 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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ABBREVIATIONS

A. janata	-	*Achaea janata*
H. armigera	-	*Helicoverpa armigera*
et al.	-	et alibi (and others)
Fig.	-	Figure
E. hirta	-	*Euphorbia hirta*
mm	-	millimeter
sp.	-	species
%	-	Per cent
cm	-	centimeter (s)
m	-	meter (s)
log	-	logarithm
°C	-	degree celsius
viz.,	-	videlicet (namely)
No.	-	number (s)
SMW	-	standard meteorological week
Edn.	-	edition
Kg.	-	Kilogram
Met.	-	Meteorological
i.e.	-	id est (that is)
S.E.	-	Standard error
C.D.	-	Critical difference
C.V.	-	Coefficient of variation
N.S.	-	Non significant
N	-	North

INTRODUCTION

Chapter I

INTRODUCTION

Castor (*Ricinus communis* Linn.) belonging to family Euphorbiaceae, is one of the important major non-edible oilseed crops. Castor is grown in tropical and subtropical regions of the world. The major castor growing countries are India, China, Brazil, Africa, USA and many Asian countries (Watt, 1892). Castor is originated in tropical belt of both India and Africa. Historically, Brazil, China and India have been key castor producing countries meeting global requirements. The world castor seed production fluctuates between 1.2 to 1.8 metric tonnes. India contributes 64 per cent of world's production and ranks first followed by China and Brazil with 23 and 7 per cent, respectively (Anonymous, 1995). In India 10.79 lakh hectares of area was under castor cultivation with average productivity of 8.00 quintals per hectare in 2000-01 (Singhal, 2003).

Major castor growing States in India are Gujrat, Andhra Pradesh, Karnataka, Orissa, Bihar, Tamil Nadu, Maharashtra and Rajasthan. In India, Gujrat ranks first in production (6.13 lakh tonnes) and productivity (15.80 quintals per hectare). In Maharashtra, the area under castor was 0.18 lakh hectare with an output to the extent of 0.04 lakh million tonnes in 2000-01.

Castor oil obtained from castor seed is of great industrial importance. It is used as a raw material in the manufacture of a number of chemicals, surfactants, soaps, surface coatings, cosmetics, pharmaceuticals, perfumes, plasticisers, greases, lubricants and rubber etc.

Castor oil is also used as medicine. The castor stalks can also be used for manufacture of paper pulp for the production of writing, printing, and wrapping papers (Patel, 1963). Castor cake is an excellent fertilizer because of high contents of nitrogen (64 per cent), phosphoric acid (2.55 per cent) and potash (1 per cent) and moisture retention.

The annual domestic consumption of castor oil in India is about 0.80 to 1.00 lakh tonnes (Singhal, 2003). According to him the soap industry, paints and allied industries and lubricants and derivative industries consume 25, 35 and 20 thousand tonnes of castor oil, respectively. The castor oil is distinguishable because of high specific gravity, thickness and hydroxyl value. The oil cake has vermicidal properties and it is used as manure in the fields, which are attacked by white ants.

Castor is attacked by 61 different kinds of insect-pests in India. The most important pests are castor semilooper (*Achaea janata* Linn.), Castor shoot and capsule borer (*Dichocrosis punctiferalis* Guen.), Tobacco caterpillar (*Spodoptera litura* Fabricius), Castor jassids (*Empoasca flavescence* Fab.), whitefly (*Trialeurodes ricini* N.) and red spider mite (*Tetranychus telarius* Linn.) (Vora *et al.*, 1984).

Castor semilooper, *Achaea janata* Linn. (Lepidoptera : Noctuidae) is one of the important pests responsible for severe economic losses in castor crop (Nair, 1986 and Kolte, 1995). The female moth lays eggs in scattered manner on lower surface of leaves. After hatching first instar larvae nibble the outer tissues of leaves, while second instar larvae bite the leaves and make the holes. The later instar larvae eat the leaves

completely leaving behind only veins. It does not attack stem and branches. In severe infestation larvae damage inflorescences and young capsules. The second and third instar larvae leaving just veins and petioles and there by causing heavy damage to castor (Khan 1946, Ayyur 1963 and Satyabrata *et al.*, 1988).

The adult moth has been reported as fruit sucking moth on citrus, guava, pomegranate and grape (Pradhan, 1967). During night hours moths damage the ripened fruits and suck fruit juices. Such fruits rot, drop down and reduce yield to a greater extent.

Castor semilooper (*A. janata*) is polyphagous in nature infesting different host plants *viz.*, castor (*Ricinus communis*), Rose (*Rosa indica*), pomegranate (*Punica granatum*), Tamrind (*Tamrindus indica*) and citrus (*Citrus aurantifolia*) etc.

The different varieties of castor may influence on growth rate, survival, reproductive potential and life-table characteristics of *A. janata* determining the population build up of the latter. This can be explained quantitatively by means of statistics. This statistics is the innate capacity for increase, which is also called the true inherent or intrinsic rate of natural increase (Birch, 1948 and Howe, 1953). The data on these aspects will be useful to determine the varieties which are resistant to *A. janata* so that a effective and long range pest management programme can be developed without affecting the quality of oil.

Considering the importance of growth and development of *A. janata* on different varieties of castor under laboratory conditions the investigations were carried out with the following objectives.

1. To study the biology of *Achaea janata* on three different varieties / hybrids of castor.
2. To study the number of larval instars of *A. janata* on two different varieties / hybrids of castor.
3. To study the life-fecundity tables of *A. janata* on three different varieties / hybrids of castor.

REVIEW OF LITERATURE

Chapter II

REVIEW OF LITERATURE

The castor semilooper (*Achaea janata,* Linnaeus) is a serious pest of castor. The moth attacks fruits of different fruit crops. There are many effective insecticides investigated by different workers for the control of this pest. However, scanty literature is available on biology, larval instars and life-fecundity tables of *A. janata* on castor. After screening the published literature in respect of *A. janata* it was observed that there is no work carried out on growth and development of *A. janata* on different varieties of castor. The review collected in respect of *A. janata* is presented under the following headings.

2.1 Host range

2.2 Biology

2.3 Biometrics

2.4 Life-fecundity tables

2.1 Host range

The larvae of *A. janata* were reported to feed on *Euphorbia bifida, E. hirta, Leucaena glauca, Desmanthus virgutus, Acasia furnesie* and *Propis chilensis* (Anonymous, 1946). Khan (1946) stated that *A. janata* feeds on rose (*Rosa* sp.), pomegranate (*Punica granatum*), *Bauhinia* sp., Ber (*Zizipus jujuba*), banian tree (*Ficus bengaliensis*) and dudhi (*Euphorbia tilufera*) in Andhra Pradesh. It was reported to feed on *Phyllanthus niruri, Achyranthus aspers* and *Ficus religious* (Pandey, 1967 and Pandey *et al.,* 1967).

The larvae were observed to feed on ornamental plants like *Dodonea viscosa* and *Quisqualis indica* at Udaipur and Jaipur in Rajasthan (Kavadia and Verma, 1973). It was recorded on soybean and

sunflower in Maharashtra (Mundhe, 1980) and Haryana (Rahilla *et al.*, 1980), respectively. It was reported to feed on *Bauhinia purpurea, Phaseolus mungo, Arachis hypogea* and *Vigna mungo* at Raichur in Karnataka (Sangappa *et al.*, 1981 and Panchbhovi and Holihosur, 1982).

2.2 Biology

2.2.1 Egg

The incubation period of *A. janata* ranged from 2 to 3 days (Khan, 1946), 3 days (Smee, 1962), 2 to 4 days (Srivastava and Pande, 1966 and Pandey, 1967) and 3 to 5 days (Pandey *et al.*, 1967 and Islam and Narsin, 1986). Karmavati and Tobing (1988) reported that the egg period of *A. janata* varied from 3 to 4 days. The incubation period of *A. janata* on castor and pomegranate was 2.02 and 3.00 days, respectively (Byale and Bilapate, 1990).

2.2.2 Larva

2.2.2.1 Larval instars

Khan (1946) reported that there were four larval instars of *A. janta* on castor. Srivastava and Pande (1966), Ramdev and Rao (1979), Islam and Narsin (1986), Byale and Bilapate (1987) and Gaikwad and Bilapate (1993) observed five larval instars on castor. However, Byale and Bilapate (1987) reported five and six larval instars when reared on castor and pomegranate, respectively.

2.2.2.2 Larval duration

The larval period of *A. janata* on castor leaves varied from 12 to 13 days (Khan, 1946), 11 to 17 days (Smee, 1962), 10 to 16 days in

monsoon and 15 to 31 days in winter season (Srivastava and Pande, 1966), 9 to 23 days (Pandey *et al.*, 1967), 8 to 12 days (Ramdev and Rao, 1979), 9 to 13 days (Islam and Narsin, 1986), 12.38 days (Karmavati and Tobing, 1988) and 12.38 days (Byale and Bilapate, 1990).

2.2.3 Pupa

The pupal duration of *A. janata* on castor varied from 11 to 27 days showing short and slightly longer period in dry and cold weather, respectively (Khan, 1946). Smee (1962), Srivastava and Pande (1966), Pandey (1967), Pandey *et al.* (1967) and Islam and Narsin (1986) observed pupal duration to the extent of 9 to 14, 10 to 15, 11 to 18, 7 to 26 and 9 to 12 days on castor leaves, respectively.

Karmavati and Tobing (1988) reported 8 to 10 days of pupal period on castor. According to Byale and Bilapate (1990), the average pupal period was 8.30 days on castor while it was 8.72 and 7.93 days in the case of male and female, respectively. Vyas (1994) reported 12 to 13 days of pupal period on rose.

2.2.4 Life cycle

The life cycle of *A. janata* was completed in 28 days in July-August and 47 days in February-March (Khan 1946). According to Pandey (1967) and Ismail and Salim (1982) the life cycle was completed in 30 and 40 to 45 days on castor, respectively.

The life cycle of *A. janata* varied from 29 to 35 days on castor in Gujrat during the active period of pest i.e. September-November (Tahiliani, 1985). The female had a shorter life cycle than a male (Byale and Bilapate, 1990). The total development of this pest was completed in 33 to 41 days on rose (Vyas, 1994).

2.2.5 Adult

2.2.5.1 Pre-oviposition

The pre-oviposition period of *A. janata* ranged from 6 to 21 days on castor (Khan, 1946). Smee (1962) observed 4 to 10 days of pre-oviposition period with 10 to 12 days of longevity of adults. According to Srivastava and Pande (1966), the female moth took 7 to 21 days as pre-oviposition period on castor. Koshiya *et al.* (1986) and Byale and Bilapate (1990) reported 5 and 3 days of pre-oviposition period of *A. janata* on castor, respectively.

2.2.5.2 Oviposition

Smee (1962) reported 5 days of oviposition period of *A. janata* on castor leaves. While Srivastava and Pande (1966) and Pandey *et al.* (1967) observed 2 to 7 and 2 to 11 days of oviposition period on castor leaves, respectively. The oviposition period to the extent of 6 and 7 days on castor leaves were noted by Koshiya *et al.* (1986) and Bilapate (1987), respectively.

2.2.5.3 Fecundity

The fecundity of female moth of *A. janata* on castor leaves was reported to be 600 (Smee, 1962), 90 to 300 (Srivastava and Pande, 1966), 622 (Pandey *et al.*, 1967), 577 (Koshiya *et al.*, 1986) and 467 eggs (Byale and Bilapate, 1987).

2.3 Biometrics

Dyar (1890) studied the head capsule width of 28 species of lepidopteran larvae and he found that width was respectively static during an instar and grow in geometric progression on successive stage of larva.

The growth ratio remains constant to particular species. It was possible to determine the exact number of instars of an insect by using this ratio.

Khan (1946) stated that the size of pupa depends upon the sex. The length and breadth of male pupa varied from 1.9 to 2.1 and 0.6 to 0.8 cm, respectively. The corresponding values in respect of female pupa were 2.0 to 2.5 and 0.7 to 0.8 cm. Srivastava and Pande (1966) observed average length and breadth of male and female pupae to the tune of 2.1, 0.63 cm and 2.3, 0.7 cm, respectively.

According to Srivastava and Pande (1966), castor was the most preferred food plant of *A. janata* followed by rose, pomegranate, ber, *Euphorbia hirta*, *Bauhinia* sp. and banian.

Subbarao and Abu Bucker (1974) studied the application of Dyar's rule to lepidopterous larvae. According to them the calculated width of successive instar was more or less equal to the observed head capsule width and grew in geometrical progression.

Based on average leaf area consumption, weight of final instar larvae and pupae, pupal period and per cent pupation, Singh (1985) reported castor as most suitable food plant of *A. janata* followed by pomegranate, ber and guava.

Byale and Bilapate (1990) observed that the larvae passed through five instars measuring 0.390, 0.706, 1.162, 1.898 and 2.769 mm head capsule width, when fed on castor leaves. They further observed that the larvae passed through six instars when reared on pomegranate leaves and their mean head capsule width was 0.361, 0.595, 0.936, 1.462, 2.124 and 2.814 mm, respectively.

2.4 Life-fecundity tables

Very limited information is available on life-fecundity tables of *A. janata* on different hosts under laboratory conditions.

Koshiya *et al.* (1986) studied the life-fecundity tables of *A. janata* at Junagadh in Gujrat State. According to them the net reproductive rate (R_o) was 577.49 indicating that *A. janata* was able to multiply 577.49 times on castor leaves at the end of each generation. The generation time (T) was 42.44 days and the intrinsic rate of natural increase (r_m) was 0.1498 with a daily finite rate of increase in numbers (λ) to the tune of 1.20.

According to Byale and Bilapate (1987) the mean generation time (T) was 37.99 days and the intrinsic rate of natural increase (r_m) was 0.1618 female per female per day. On reaching the stable age-distribution the population of *A. janata* on castor in its various stages viz., egg, larva, pupa and adult contributed to the extent of 49.06, 48.06, 2.50 and 0.34 per cent, respectively. According to Gaikwad and Bilapate (1993) the net reproductive rate of *A. janata* was 325.94, 150.25, 151.84 and 101.98 on castor, pomegranate *L. siceraria* and rose, respectively.

Similar studies on life-fecundity tables have been reported in the case of *Trogoderma granarium* Everts (Atwal *et al.*, 1968), *Trichogramma* sp. (Orphanides and Gonzales, 1971), *Eriborus trochan teratus* Morley (Chundurwar and Rao, 1975), *Dichocrosis punctiferalis* Guenee (Bilapate, 1977), *Agathis unicolorate* (Shenefelt) (Chundurwar, 1977), *Heliothis armigera* (Hubner) (Bilapate *et al.*, 1980), *Spodoptera litura* (Bilapate *et al.*, 1980) and *Utethesia pulchella* Lin. (Bilapate, 1984).

MATERIAL AND METHODS

Chapter III

MATERIAL AND METHODS

The investigations were carried out to study the growth and development of *Achaea janata* on different varieties of castor viz., DCH-177, Western and Anirudha at the department of Entomology, College of Agriculture, Latur during 2004-05. The material and methods used in these experiments are presented under the following heads.

3.1 Rearing of test insect

3.2 Biology of *A. janata* on different varieties of castor

3.3 Biometrics of *A. janata* on different varieties of castor

3.4 Life-fecundity tables of *A. janata* on different varieties of castor

3.1 Rearing of test insect

The initial culture of castor semilooper, *Achaea janata* (Noctuidae : Lepidoptera) was developed by collecting large number of larvae from the field of castor. The collected larvae were reared individually in the round clean plastic boxes. Fresh castor leaves were provided as food to these larvae everyday till pupation. The sexes were determined in pupal stage. The adults emerged on the same day were placed in oviposition cage for the purpose of egg laying. The cotton swabs dipped into 5 per cent honey solution was provided as food to the adults. A bouquet of fresh castor leaves was kept into the conical flask containing water for the purpose of egg laying.

The eggs laid by female moths were used for investigation on biology, biometrics and life-fecundity of *A. janata* on different varieties of castor. During the course of investigations (August 04 to October 04), the prevailing laboratory minimum and maximum

temperatures ranged from 20.2 to 23.1^{0}C and 28.9 to 33.1^{0}C, respectively (Appendix II).

3.2 Biology of *A. janata* on different varieties of castor

The studies on biology of *A. janata* were carried out in a completely randomized design replicated five times. There were three varieties of castor viz., DCH-177, Western and Anirudha. These varieties were sown in a gross plot size of 10 x 10 m each at the distance of 60 x 60 cm on the farm of College of Agriculture, Latur during kharif 2004-05. The another set of the same varieties was also sown at an interval of 15 days after first sowing in order to have continuous supply of fresh leaves to the test insect under study (PLATE I). One hundred eggs of *A. janata* were obtained from oviposition cage. They were transferred on moist tissue paper kept in a petriplates with a total of 20 eggs in each petriplate as one replication. The observations on incubation period and per cent egg hatch were recorded. The newly hatched larvae were reared individually in clean plastic boxes containing fresh castor leaves of respective varieties of castor. The observations on larval duration, per cent larvae pupated, pre-pupal and pupal duration, pupal length, width and weight, per cent adult emergence and life-cycle duration of male and female were recorded on DCH-177, Western and Anirudha varieties of castor. The adults emerged on the same day were paired and released in oviposition cage. A bouquet of fresh castor leaves of respective varieties was kept in a conical flask containing water. The same was transferred in the oviposition cage as substrate for egg laying. The cotton swabs dipped into 5 per cent honey solution was provided as food to the moths in oviposition cage. The observations on pre-oviposition and oviposition period were recorded. The number of eggs laid by each female was

PLATE I : A view of experimental castor crop

counted daily till her death. The growth index was calculated by using following formula :

$$\text{Growth index} = \frac{\text{Percent larvae pupated}}{\text{Mean larval duration}}$$

3.3 Biometrics of *A. janata* on different varieties of castor

Five hundred larvae immediately after hatching were transferred in separate clean plastic boxes containing tender castor leaves of respective varieties. The food was changed daily in the morning. In each instar immediately after moulting the head capsule width and body length and width of each larva were measured to the nearest value of 0.0122 mm with the help of occular and stage micrometer. Thirty larvae were killed in order to record these biometrical observations in each instar. The biometrical studies of *A. janata* on Anirudha variety of castor were not carried out for want of sufficient culture. The larval instar duration of *A. janata* was observed on DCH-177 and Western varieties of castor. The application of Dyar's rule (1890) was tested for the number of larval instars when reared on different varieties of castor. The regression relationship between the instar and mean value of head capsule width and body length and width of larva in different instars was calculated using the following formula:

$$\text{Log}_{10} Y = a + bx.$$

Where,

Y	=	Head capsule width / body length / body width of larva (mean)
a	=	Constant
b	=	Logarithm of growth ratio
x	=	Number of instars

3.3.1 Growth ratio

It was calculated by dividing the mean value of head capsule width/ body length / body width of larval instar by the mean value of head capsule width / body length / body width of preceding larval instar.

3.3.2 Progression factor

It is the average of growth ratio.

3.4 Life-fecundity tables of *A. janata* on different varieties of castor

The life-fecundity tables of *A. janata* on different varieties of castor viz., DCH-177, Western and Anirudha were prepared by using 100 eggs kept in 5 petriplates containing 20 each. Soon after hatching all larvae were reared individually in clean plastic boxes. The tender leaves of respective varieties of castor were provided as food daily till pupation. The observations on hatching, larval and pupal development, successful adult emergence, fecundity and age-specific mortality in eggs, larvae, pre-pupae, pupae and adults were recorded daily. In order to determine life-fecundity the number of adults emerged on a particular day were transferred to oviposition cage for egg laying. A bouquet of healthy twigs of respective varieties of castor was kept as oviposition substrate in egg laying cage. The cotton swabs dipped into 5 per cent honey solution was provided daily as food to moths. According to Southwood (1968), the number of female births (m_x) was calculated by diving number of eggs laid per female by two considering sex ratio of 1 : 1.

The life-fecundity tables under laboratory conditions were constructed by using following column heading 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'

3.4.1 Net reproductive rate

From the data the value of 'x', 'l_x' and 'm_x' was calculated on different varieties of castor. The sum of products '$l_x m_x$' is net reproductive rate represented by R_o (Lokta, 1925). The net reproductive rate is the rate of multiplication of 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.

$$R_0 = \Sigma l_x m_x$$

3.4.2 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

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

3.4.3 Innate capacity for increase in numbers

The observations on number of individuals observed and mean number of female offspring produced at each age interval was recorded. From the data, the arbitrary value of innate capacity for

increase in numbers 'r_c' was calculated by using the 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 three 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).

$$\Sigma\, e^{7-rm\,x}\, l_x\, m_x = 1096.6$$

Table was then constructed with column 'x' and '$l_x\, m_x$' for each trial 'r_m'. The three 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:

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

3.4.4 The finite rate of natural increase (λ)

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

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

3.4.5 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, pre-pupa, pupa and adult, the expected percentage distribution of each stage in a stable age-distribution was calculated.

RESULTS

Chapter IV

RESULTS

The studies on growth and development of *A. janata* on different varieties of castor were undertaken at the department of Entomology, College of Agriculture, Latur during 2004-05. The results obtained in the present investigation are reported under following heads.

4.1 Biology of *A. janata* on different varieties of castor

4.2 Biometrics of *A. janata* on different varieties of castor

4.3 Life-fecundity tables of *A. janata* on different varieties of castor

4.1 Biology of *A. janata* on different varieties of castor

4.1.1 Egg

The statistically significant differences were obtained in respect of incubation period of *A. janata* on different varieties of castor (Table 1). The mean incubation period varied from 1.87 to 3.00 days. The minimum mean incubation period to the extent of 1.87 days was observed on hybrid variety of castor viz., DCH-177 followed by Western (2.73 days) and Anirudha (3.00 days).

4.1.2 Larva

The mean larval duration, growth index and per cent larvae pupated in respect of *A. janata* differed significantly when it was reared on different varieties of castor (Table 1).

Table 1 : The mean egg and larval duration, per cent pupation and growth index of *A. janata* on different varieties of castor.

Variety	Incubation period (days)	Larval duration (days)	Per cent larvae pupated	Growth index
DCH-177	1.87	13.65	58.00	4.22
Western	2.73	11.79	66.00	5.56
Anirudha	3.00	12.79	23.00	1.79
S.E. ±	0.04	0.03	4.33	0.85
C.D. at 5%	0.13	0.11	13.34	2.61
C.V. (%)	5.33	2.09	21.91	17.32

It is evident from Table 1 that the shortest mean larval duration to the tune of 11.79 days was observed on Western followed by Anirudha (12.79 days) and DCH-177 (13.65 days). The growth index varied from 1.79 to 5.56. The significantly highest growth index was observed in the case of those larvae, which were fed on the leaves of Western (5.56) followed by DCH-177 (4.22) and Anirudha (1.79). However, the growth index was at par among the larvae fed on DCH-177 and Anirudha. The significantly highest pupation to the extent of 66 per cent was observed in the case of larvae, which were reared on Western followed by DCH-177 (58 per cent) and Anirudha (23 per cent).

4.1.3 Pupa

The non-significant differences were observed in respect of pre-pupal duration. While pupal duration and adult emergence differed significantly when larvae were reared on different varieties of castor (Table 2).

Table 2 : The mean pre-pupal and pupal duration, per cent adult emergence and life cycle duration of *A. janata* on different varieties of castor.

Variety	Pre-pupal duration (days)	Pupal duration (days)	Per cent adult emer-gence	Life cycle duration (days)		
				General	Male	Female
DCH-177	1.71	10.19	55.00	28.47	28.72	27.90
Western	1.85	9.57	65.00	27.01	27.14	26.89
Anirudha	1.97	10.55	23.00	29.24	29.65	29.16
S.E. ±	0.02	0.02	4.14	0.02	0.02	0.03
C.D. at 5%	N.S.	0.05	12.78	0.06	0.08	0.09
C.V. (%)	3.84	1.12	21.39	0.86	1.20	1.33

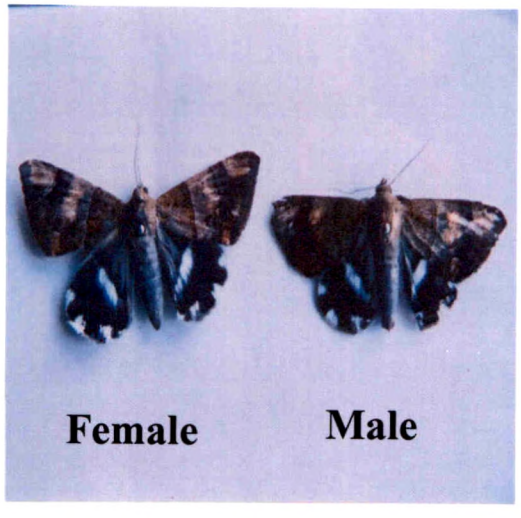
The data presented in Table 2 indicated that the pre-pupal duration was observed to be shortest on hybrid variety, DCH-177 (1.71 days), while the pest completed the shortest mean pupal duration to the extent of 9.57 days on Western. The significantly lowest percent adult emergence was observed in the case of larvae which were reared on Anirudha variety of castor (23 per cent) followed by DCH-177 (55 per cent) and Western (65 per cent).

4.1.4 Life cycle

The significant differences were observed in respect of general life cycle duration of *A. janata* when reared on different varieties of castor (Table 2) (PLATE II). The mean life cycle duration in general was observed to be highest (29.24 days) on Anirudha followed by DCH-177 (28.47 days) and Western (27.01 days).

Eggs

Caterpillar



Adults

Pupae

PLATE II: Life stages of *A.janata* on castor

The mean life cycle duration of male and female *A. janata* was also differed significantly when their larvae were fed on different varieties of castor (Table 2). The highest mean life cycle duration of male and female to the extent of 29.65 and 29.16 days respectively was observed on Anirudha followed by DCH-177 (28.72 and 27.90 days) and Western (27.14 and 26.89 days). In general, male had longer life cycle than female.

It is evident from Table 3 that non-significant differences were observed in respect of pupal length and width of general, male and female *A. janata* excepting general pupal length. The significantly highest general pupal length (23.59 mm) of *A. janata* was recorded on Anirudha variety of castor followed by Western (22.99 mm) and DCH-177 (22.64 mm). The pupal length of male and female varied from 22.73 to 22.99 mm and 22.58 to 24.20 mm, respectively. The corresponding values in respect of pupal width were 11.82 to 12.32 and 12.06 to 12.30 mm, respectively. The general pupal width ranged from 12.02 to 12.26 mm.

Significantly highest pupal weight to the extent of 880, 910 and 890 mg was observed in the case of general, male and female *A. janata*, respectively when reared on Anirudha variety of castor followed by DCH-177 (830, 830 and 840 mg) and Western (780, 780 and 790 mg).

Table 3 : Pupal length, width and weight of *A. janata* on different varieties of castor.

Variety	Pupal length (mm)			Pupal width (mm)			Pupal weight (mg)		
	General	Male	Female	General	Male	Female	General	Male	Female
DCH-177	22.64	22.73	22.58	12.26	12.32	12.19	830	830	840
Western	22.99	22.93	22.88	12.02	11.92	12.06	780	780	790
Anirudha	23.59	22.99	24.20	12.07	11.82	12.30	880	910	890
S.E. ±	0.22	0.24	0.65	0.11	0.15	0.17	13.50	29.25	18.06
C.D. at 5%	0.66	N.S.	N.S.	N.S.	N.S.	N.S.	41.51	89.98	55.52
C.V. (%)	2.08	2.36	6.29	1.96	2.79	3.19	3.61	7.74	4.77

The results on pre-oviposition, oviposition and fecundity of *A. janata* on different varieties of castor are summarized in Table 4.

Table 4 : The mean pre-oviposition, oviposition and fecundity of *A. janata* on different varieties of castor.

Variety	Pre-oviposition period (days)	Oviposition period (days)	Fecundity / female
DCH-177	3.00	10.70	526.40
Western	2.50	9.00	441.50
Anirudha	2.90	7.70	417.50
S.E. ±	0.05	0.07	0.58
C.D. at 5%	0.16	0.22	1.68
C.V. (%)	9.90	7.92	8.61

The data (Table 4) revealed that mean pre-oviposition period ranged from 2.50 to 3.00 days when larvae reared on different varieties of castor. The significantly lowest pre-oviposition period (2.50 days) was recorded in the case of those larvae that were fed on the leaves of Western variety of castor followed by Anirudha (2.90 days) and DCH-177 (3.00 days). However, significantly highest oviposition period was observed on DCH-177 (10.70 days) followed by Western (9.00 days) and Anirudha (7.70 days). The significantly highest number of eggs (526.40) were laid by the female moths emerged from those larvae which were reared on DCH-177 variety of castor followed by Western (441.50) and Anirudha (417.50).

4.2 Biometrics of *A. janata* on different varieties of castor

Biometrical observations of *A. janata* were recorded on DCH-177 and Western varieties of castor. However, these studies were not carried out on Anirudha variety of castor for want of culture of test insect.

4.2.1 Head capsule width

4.2.1.1 DCH-177

The data in respect of head capsule width of *A. janata* on DCH-177 are presented in Table 5 and Fig. 1.

Table 5 : Comparison of observed and calculated values of mean measurements of larval head capsule width (mm) of *A. janata* on DCH-177.

Parameter	Larval instars					Progression factor
	I	II	III	IV	V	
Observed head capsule width (mm) ± S.E.	0.37 ± 0.01	0.91 ± 0.01	1.50 ± 0.03	2.70 ± 0.04	3.91 ± 0.06	
Growth ratio	-	2.44	1.66	1.79	1.26	1.79
Calculated head capsule width (mm)	0.45	0.78	1.36	2.36	4.10	
Growth ratio	-	1.74	1.74	1.74	1.74	1.74
Difference	- 0.08	0.12	0.14	0.33	- 0.70	
Per cent difference	-21.30	13.61	9.55	12.51	-20.48	

The results presented in Table 5 revealed that the larvae of *A. janata* when reared on DCH-177 variety of castor passed through five instars (PLATE III). The mean larval head capsule width increased from 0.37 ± 0.01 (first instar) to 3.91 ± 0.06 mm (last instar). The mean progression factor for observed and calculated head capsule width was 1.79 and 1.74, respectively. The equation for the straight line best fitting the observed head capsule width was $\log_{10} Y = - 0.5863 + 0.2399 x$.

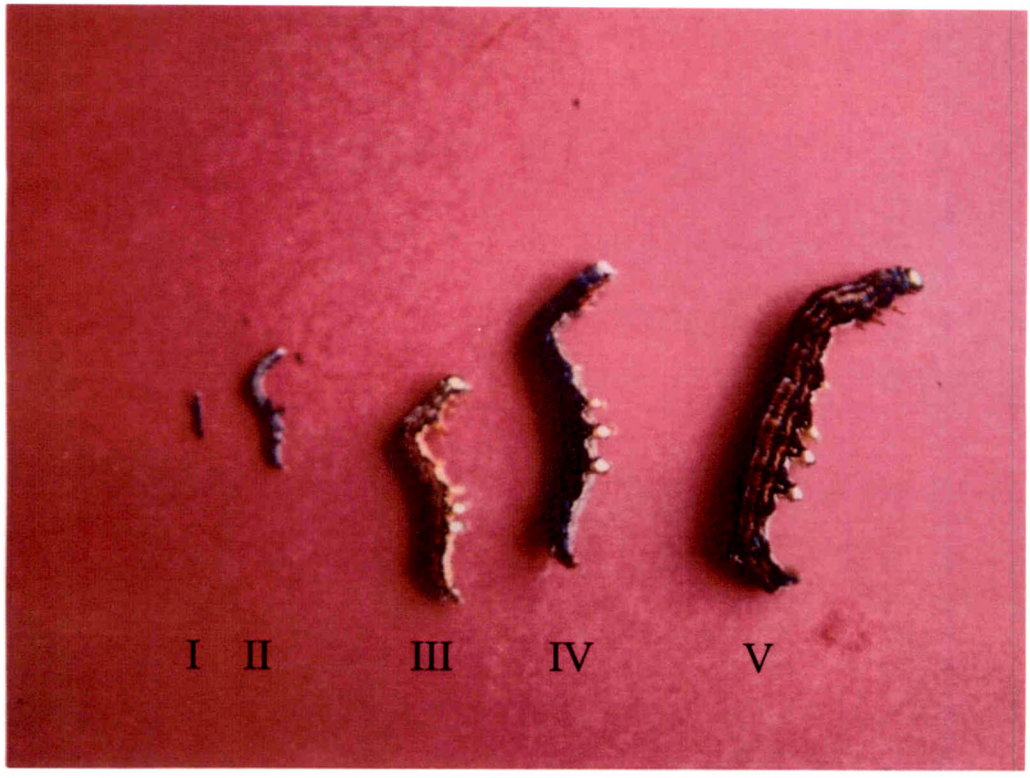


PLATE III: Larval instars of *A. janata* on castor

4.2.1.2 Western

The data in respect of observed and calculated mean head capsule width of successive instars of *A. janata* on Western are presented in Table 6 and Fig. 1.

Table 6 : Comparison of observed and calculated values of mean measurements of larval head capsule width (mm) of *A. janata* on Western.

Parameter	Larval instars					Progression factor
	I	II	III	IV	V	
Observed head capsule width (mm) ± S.E.	0.50 ± 0.02	0.96 ± 0.02	1.55 ± 0.08	2.72 ± 0.03	3.50 ± 0.03	
Growth ratio	-	1.92	1.62	1.75	1.29	1.65
Calculated head capsule width (mm)	0.55	0.90	1.47	2.42	3.97	
Growth ratio	-	1.64	1.64	1.64	1.64	1.64
Difference	- 0.05	0.05	0.07	0.30	- 0.47	
Per cent difference	-10.30	5.74	4.82	11.00	-13.47	

It is evident from Table 6 that the larvae also passed through five instars when reared on Western. The mean larval head capsule width varied from 0.50 ± 0.02 to 3.50 ± 0.03 mm for I to V instar. The mean observed and calculated progression factors of head capsule width were 1.65 and 1.64, respectively. The equation for the straight line best fitting the observed head capsule width was $\log_{10} Y = 0.4750 + 0.2147 x$.

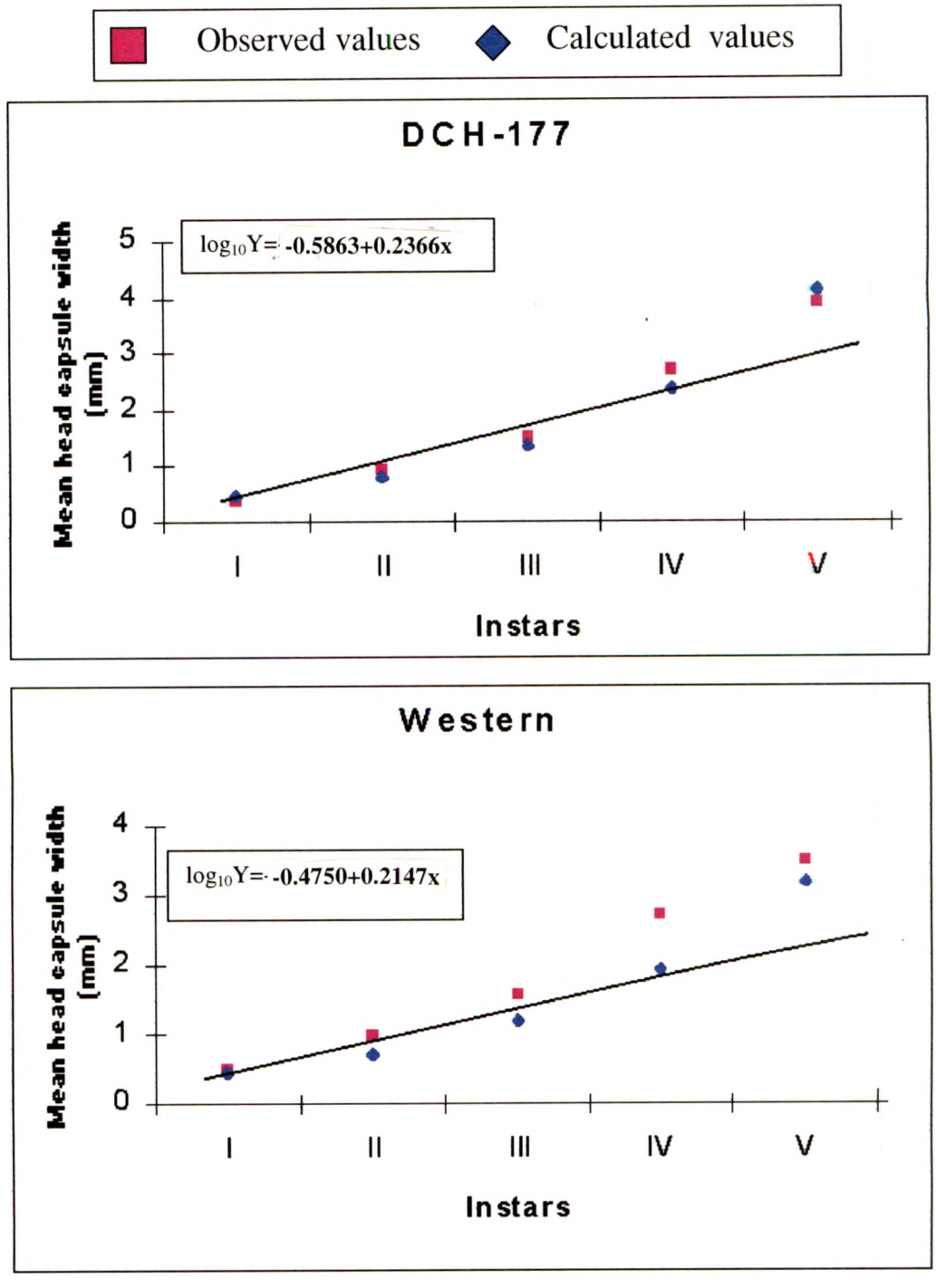


Fig.1: Regression graph of larval instars on mean head capsule width of *A.janata* observed on DCH-177 and Western varieties of castor

4.2.2 Larval body length

4.2.2.1 DCH-177

The measurements of the larval body length of *A. janata* when reared on DCH-177 are tabulated in Table 7 and graphically presented in Fig. 2.

Table 7 : Comparison of observed and calculated values of mean measurements of larval body length (mm) of *A. janata* on DCH-177.

Parameter	Larval instars					Progression factor
	I	II	III	IV	V	
Observed body length (mm)± S.E.	2.61 ± 0.02	7.33 ± 0.20	16.28 ± 0.26	27.31 ± 0.39	43.18 ± 0.68	
Growth ratio	-	2.81	2.22	1.68	1.58	2.07
Calculated body length (mm)	3.25	6.49	12.97	25.92	51.81	
Growth ratio	-	1.99	1.99	1.99	1.99	1.99
Difference	- 0.63	0.84	3.31	1.38	- 8.63	
Per cent difference	-24.27	-11.48	20.33	5.05	-19.98	

The results (Table 7) indicated that the larval body length of last instar was 43.18 ± 0.68 mm. The mean observed and calculated progression factors were 2.07 and 1.99, respectively. The regression equation was $\log_{10} Y = 0.2109 + 0.3007 x$.

4.2.2.2 Western

The data on larval body length of *A. janata* when reared on Western variety of castor are presented in Table 8 and Fig. 2.

Table 8 : Comparison of observed and calculated values of mean measurements of larval body length (mm) of *A. janata* on Western.

Parameter	Larval instars					Progression factor
	I	II	III	IV	V	
Observed body length (mm)± S.E.	2.80 ± 0.03	8.04 ± 0.12	16.68 ± 0.22	27.41 ± 0.39	40.26 ± 0.95	
Growth ratio	-	2.87	2.07	1.63	1.47	2.01
Calculated body length (mm)	3.26	5.73	10.07	17.69	31.09	
Growth ratio	-	1.76	1.76	1.76	1.76	1.76
Difference	- 0.46	2.31	6.61	9.72	9.17	
Per cent difference	-16.59	28.72	39.64	35.45	22.78	

The data presented in Table 8 revealed that the larval body length increased from 2.80 ± 0.03 (first instar) to 40.26 ± 0.95 mm (fifth instar). The mean progression factors for observed and calculated body length of larva were 2.01 and 1.76, respectively. The regression equation was $\log_{10} Y = 0.2686 + 0.2448 x$.

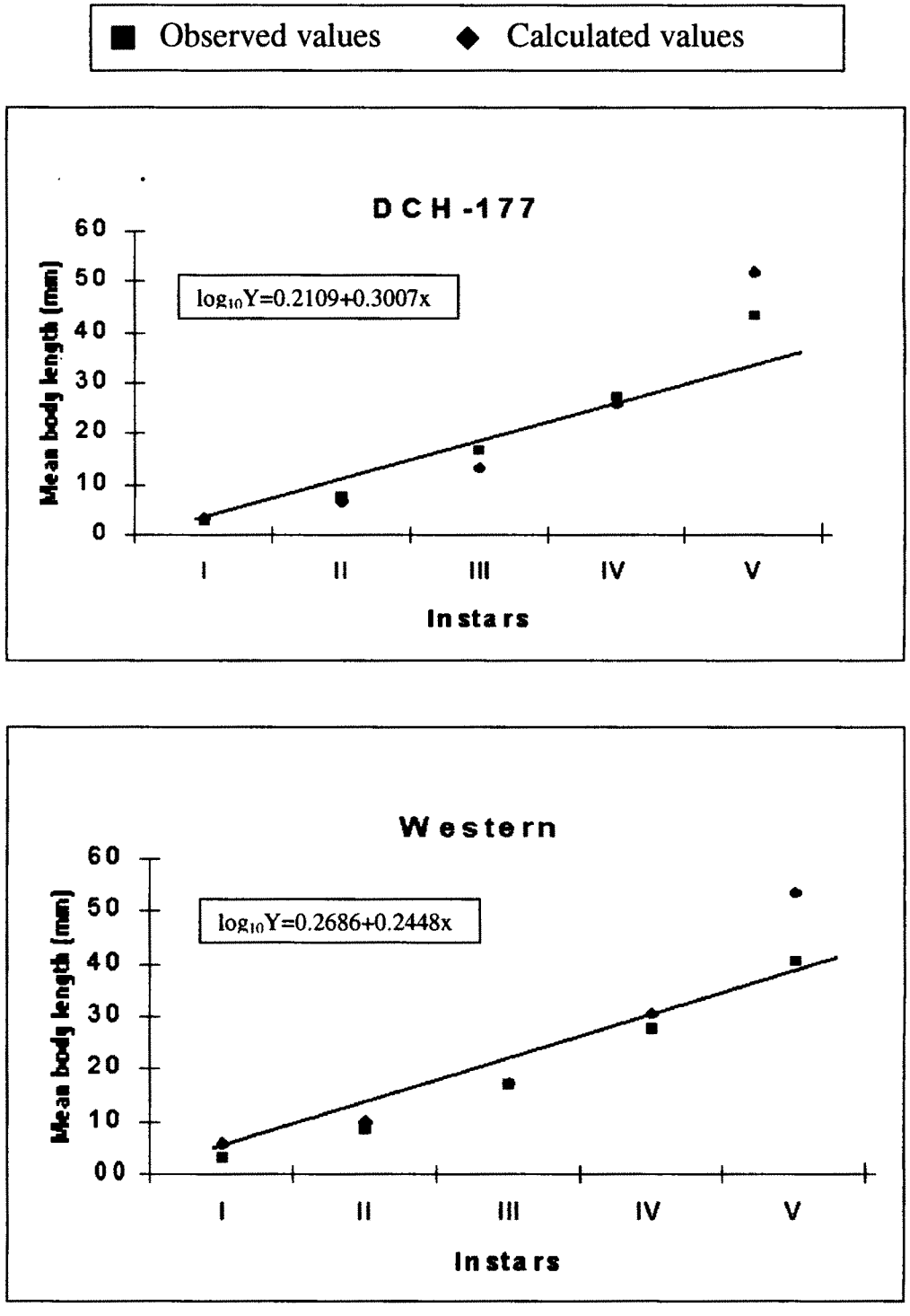


Fig. 2: Regression graph of larval instars on mean body length of *A.janata* observed on DCH-177 and Western varieties of castor

4.2.3 Larval body width

4.2.3.1 DCH-177

The data in respect of observed body width of different instars of *A. janata* when reared on DCH-177 variety of castor are presented in Table 9 and Fig 3.

Table 9 : Comparison of observed and calculated values of mean measurements of larval body width (mm) of *A. janata* on DCH-177.

Parameter	Larval instars					Progression factor
	I	II	III	IV	V	
Observed body width (mm)± S.E.	0.25 ± 0.00	0.84 ± 0.02	1.68 ± 0.02	2.81 ± 0.03	3.63 ± 0.05	
Growth ratio	-	3.32	2.00	1.67	1.29	2.08
Calculated body width (mm)	0.35	0.67	1.30	2.49	4.78	
Growth ratio	-	1.92	1.92	1.92	1.92	1.92
Difference	- 0.10	0.17	0.39	0.32	- 1.15	
Per cent difference	-38.55	19.81	22.99	11.55	-31.83	

The results (Table 9) indicated that the larval body width of last instar when moulted five times was 3.63 ± 0.05 mm. The mean progression factors for observed and calculated larval body width were 2.08 and 1.92, respectively. By the method of least squares, the values for 'a' and 'b' were $\log_{10} Y = - 0.7385 + 0.2836 x$.

4.2.3.2 Western

The mean observed and calculated progression factors for larval body width of *A. janata* when reared on Western variety of castor are presented in Table 10 and Fig. 3.

Table 10: Comparison of observed and calculated values of mean measurements of larval body width (mm) of *A. janata* on Western.

Parameter	Larval instars					Progression factor
	I	II	III	IV	V	
Observed body width (mm)± S.E.	0.44 ± 0.01	0.98 ± 0.02	1.71 ± 0.03	2.86 ± 0.03	3.40 ± 0.03	
Growth ratio	-	2.23	1.75	1.67	1.99	1.71
Calculated body width (mm)	0.53	0.88	1.48	2.49	4.17	
Growth ratio	-	1.68	1.68	1.68	1.68	1.68
Difference	- 0.09	0.10	0.23	0.38	- 0.77	
Per cent difference	-20.07	9.59	13.52	13.21	-22.52	

The mean body width of last instar was 3.40 ± 0.03 mm (Table 10). The mean progression factors for observed and calculated larval body width were 1.71 and 1.68, respectively. The regression equation was $\log_{10} Y = - 0.5028 + 0.2246 x$.

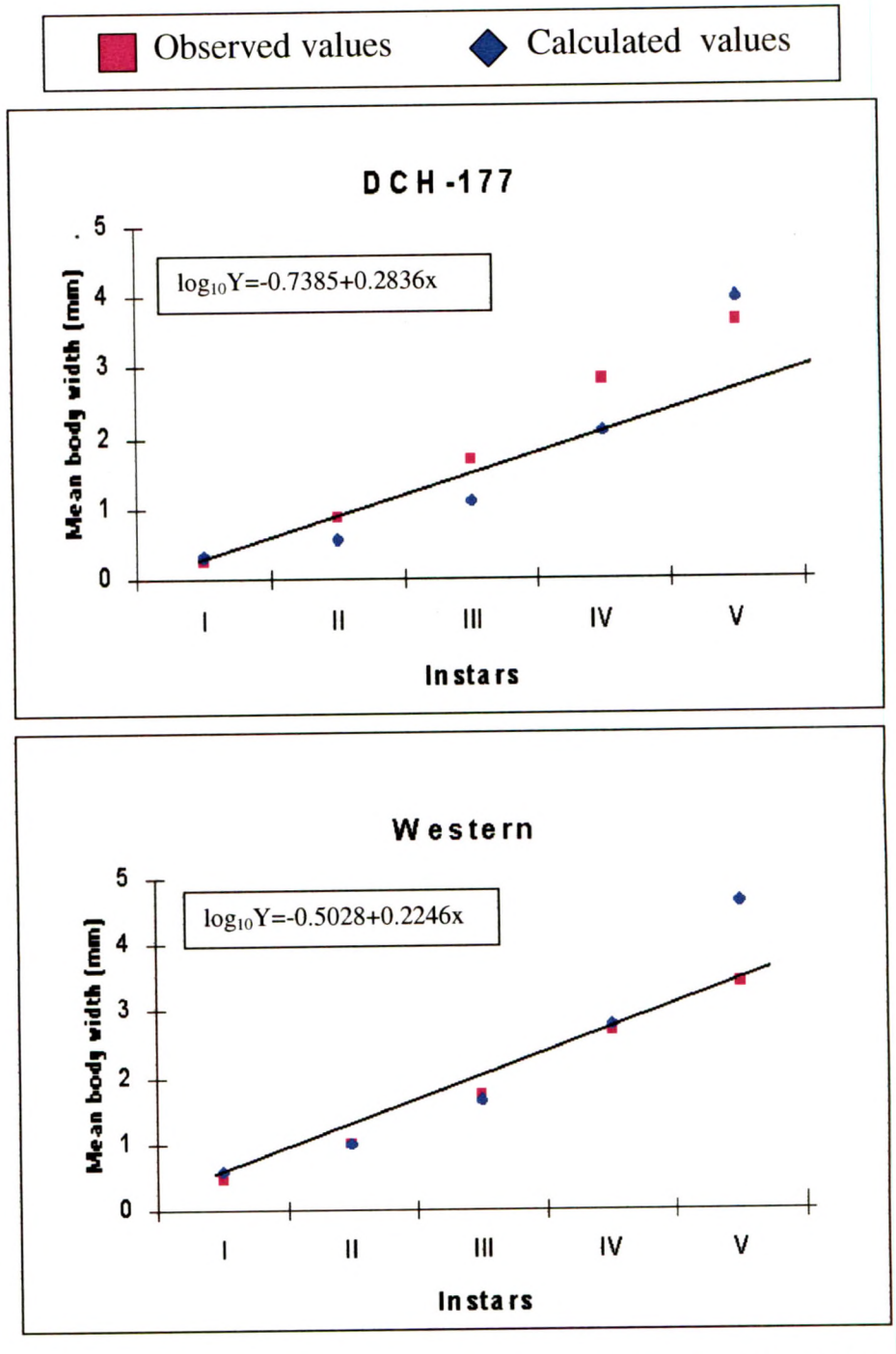


Fig. 3: Regression graph of larval instars on mean body width of *A.janata* observed on DCH-177 and Western varieties of castor

4.2.4 Larval instar duration

The data in respect of larval instar duration of *A. janata* on DCH-177 and Western varieties of castor are presented in Table 11.

Table 11 : The mean larval instar duration of *A. janata* on different varieties of castor.

Variety	Larval instar duration (days)					Total	Mean
	I	II	III	IV	V		
DCH-177	3.0	2.0	3.0	3.0	5.0	16.0	3.2
Western	3.0	3.0	2.0	4.0	5.0	17.0	3.4
Mean	3.0	2.5	2.5	3.5	5.0	16.5	3.3

It is evident from Table 11 that the larval instar duration of *A. janata* for I to V instar when reared on DCH-177 was 3, 2, 3, 3 and 5 days respectively. The corresponding values on Western were 3, 3, 2, 4 and 5 days.

4.3 Life-fecundity tables of *A. janata* on different varieties of castor

The life-fecundity tables of *A. janata* were constructed on three varieties of castor *viz.*, DCH-177, Western and Anirudha. The observations were made on hatching of eggs, larval, pre-pupal and pupal mortality in respective pivotal age. The fecundity and age-specific mortality of females were also studied.

4.3.1 Life-fecundity tables of *A. janata* on DCH-177

The data pertaining to life-tables and age-specific fecundity of *A. janata* on DCH-177, hybrid variety of castor are presented in Table 12 to 16.

Table 12 : Survival of life stages of *A. janata* during development on DCH-177.

Number of eggs observed	Number surviving					
	Egg duration (0-2 days)	Larval duration (3-20 days)	Pre-pupal duration (21-23 days)	Pupal duration (24-35 days)	Adult emergence	
					Male	Female
20	20	14	13	11	6	5
20	20	12	12	12	8	4
20	20	14	14	13	7	6
20	20	15	15	15	6	9
20	07	04	04	14	2	2
100	87	59	58	55	29	26

The results tabulated in Table 12 indicated that *A. janata* survived to the extent of 87, 59, 58 and 55 per cent in egg, larval, pre-pupal and pupal stages, respectively in a cohort of 100 eggs. During the course of rearing from egg to adult emergence, 29 and 26 per cent male and female moths, respectively were emerged successfully.

It is evident from Table 13 and Fig. 4 that the survival (l_x) was 0.55 per individual within a pivotal age of 35 days on DCH-177. The pre-oviposition period ranged from 36th to 37th days of pivotal age. The number of eggs laid per female was divided by two to get the number of female births (m_x). The highest female births (38.70) were observed on 4th day of oviposition at 41st day of pivotal age. The female births were fluctuating up to 46th day of pivotal age. Thereafter female births decreased gradually. The first female mortality was observed on 46th day (l_x = 0.54) of pivotal age. The net reproductive rate (R_o) representing the

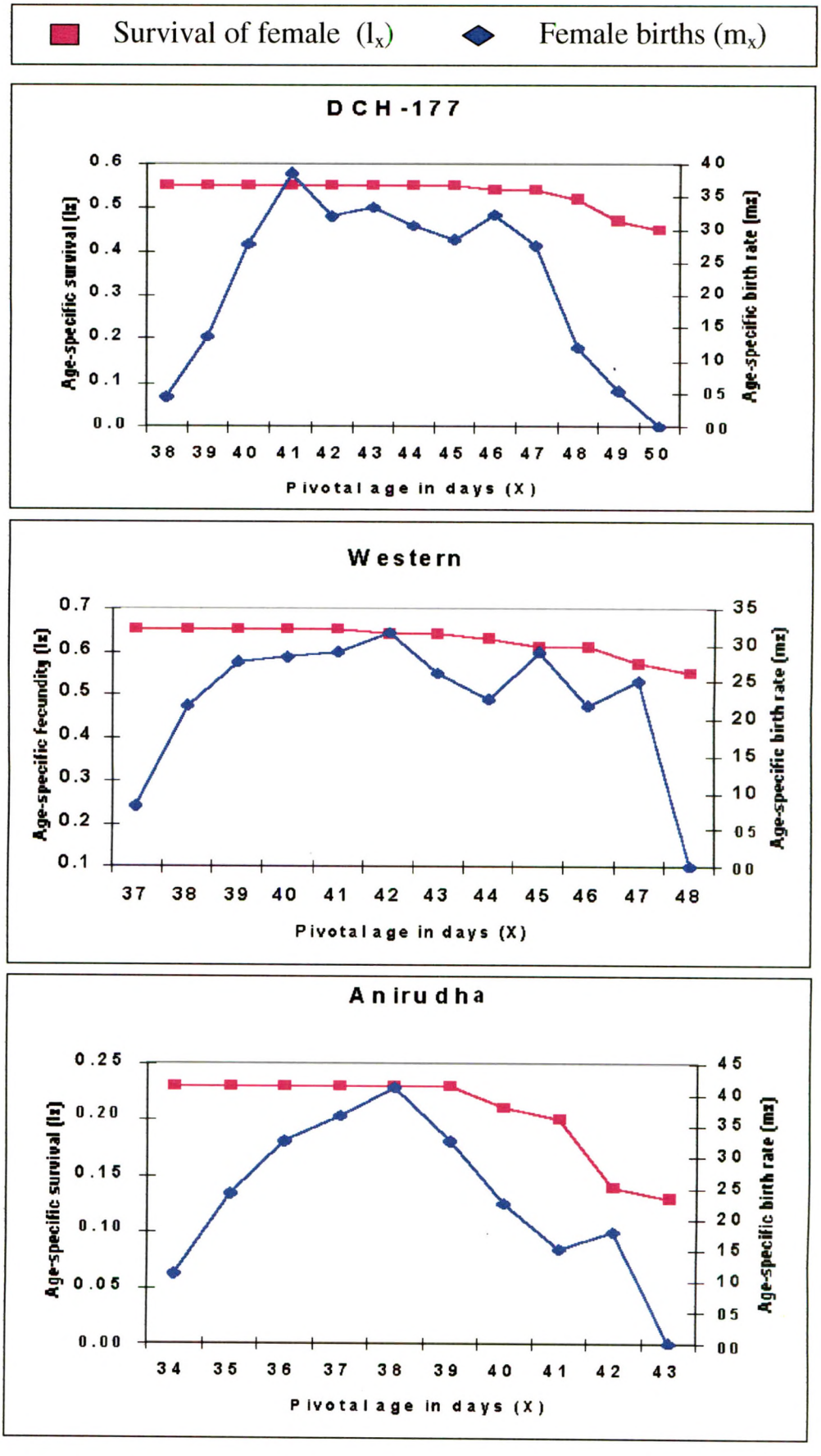


Fig. 4: Daily age-specific survival and fecundity of *A. janata* on different varieties of castor

total females per female per generation was 155.87. Thus the population of *A. janata* was able to multiply 155.87 times per generation on DCH-177.

Table 13: Life-table and age-specific fecundity of *A. janata* on DCH-177.

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	0.55	Immature stages		
36-37	0.55	Pre-oviposition period		
38	0.55	4.50	2.47	93.86
39	0.55	13.55	7.45	290.55
40	0.55	27.75	15.26	610.40
41	0.55	38.70	21.28	872.48
42	0.55	31.90	17.54	736.68
43	0.55	33.35	18.34	788.62
44	0.55	30.65	16.85	741.40
45	0.55	28.45	15.64	703.38
46	0.54	32.33	17.45	802.70
47	0.54	27.45	14.82	696.54
48	0.52	11.92	6.19	297.12
49	0.47	5.50	2.58	126.42
50	0.45	0.00	0.00	0.00
			ΣI_xm_x= 155.87	ΣI_xm_xX= 6760.15

The results in respect of mean length of generation, intrinsic rate of increase in numbers and finite rate of increase in numbers (λ) of *A. janata* on DCH-177 are summarized in Table 14.

Table 14 : Mean length of generation, innate capacity for increase in numbers and finite rate of increase in numbers of *A. janata* on DCH-177.

Population growth statistics	
Mean length of generation $T_c = \frac{\Sigma l_x m_x X}{R_0}$	43.37 days
Innate capacity for increase in numbers $r_c = \frac{\text{Log}_e R_o}{T_c}$	0.1164 female/female/day
Arbitrary $r_m(r_c)$ 0.11, 0.12, 0.13 corrected r_m $\Sigma e^{7-rmx} l_x m_x$= 1096.6 Corrected generation time	0.1183 female/female/day
$T = \frac{\text{Log}_e R_o}{r_m}$	42.68 days
Finite rate of increase in numbers (λ) λ = anti $\log_e r_m$	1.1255 Females/female/day

The mean length of generation (T_c) was found to be 43.37 days. The arbitrary value for intrinsic rate of natural increase (r_c) was 0.1164 female per female per day. The precise generation time (T) was 42.68 days, while the finite rate of increase in numbers (λ) was 1.1255 females per female per day. The corrected innate capacity for increase in numbers (r_m) was 0.1183 female per female per day.

Three trial values of 1524.52, 995.35 and 650.42 were plotted on horizontal axis against their respective arbitrary (r_c) differing in second decimal place on either side of it i.e. 0.11, 0.12 and 0.13 on vertical axis and corrected (r_m) was calculated by interpolation method (Table 15). Thus the corrected (r_m) was calculated as 0.1183 female per female per day (Fig. 5).

Table 15 : Calculation of r_m by trial and error method on DCH-177.

Pivotal age	$l_x m_x$	$r_m = 0.11$		$r_m = 0.12$		$r_m = 0.13$	
		$e^{(7-rmx)}$	$e^{(7-rmx}$ $l_xm_x)$	$e^{(7-rmx)}$	$e^{(7-rmx}$ $l_xm_x)$	$e^{(7-rmx)}$	$e^{(7-rmx}$ $l_xm_x)$
38	2.47	16.77	41.43	11.47	28.33	7.85	19.38
39	7.45	15.02	111.96	10.17	75.80	6.88	51.32
40	15.26	13.46	205.54	9.03	137.72	6.05	92.31
41	21.28	12.06	256.66	8.00	170.33	5.31	113.04
42	17.54	10.80	189.52	7.09	124.52	4.66	81.82
43	18.34	9.68	177.52	6.29	115.48	4.09	75.12
44	16.85	8.67	146.11	5.58	94.09	3.59	60.60
45	15.64	7.77	121.49	4.95	77.42	3.16	49.39
46	17.45	6.96	121.43	4.39	76.66	2.77	48.39
47	14.82	6.23	92.39	3.89	57.74	2.44	36.08
48	6.19	5.58	34.56	3.45	21.39	2.14	13.24
49	5.58	5.00	25.91	3.06	15.87	1.88	9.73
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		118.00	1524.52	77.37	995.35	50.82	650.42

The contribution made by different developmental stages towards stable age- distribution of *A. janata* on DCH-177 was determined and data are presented in Table 16 and Fig. 6.

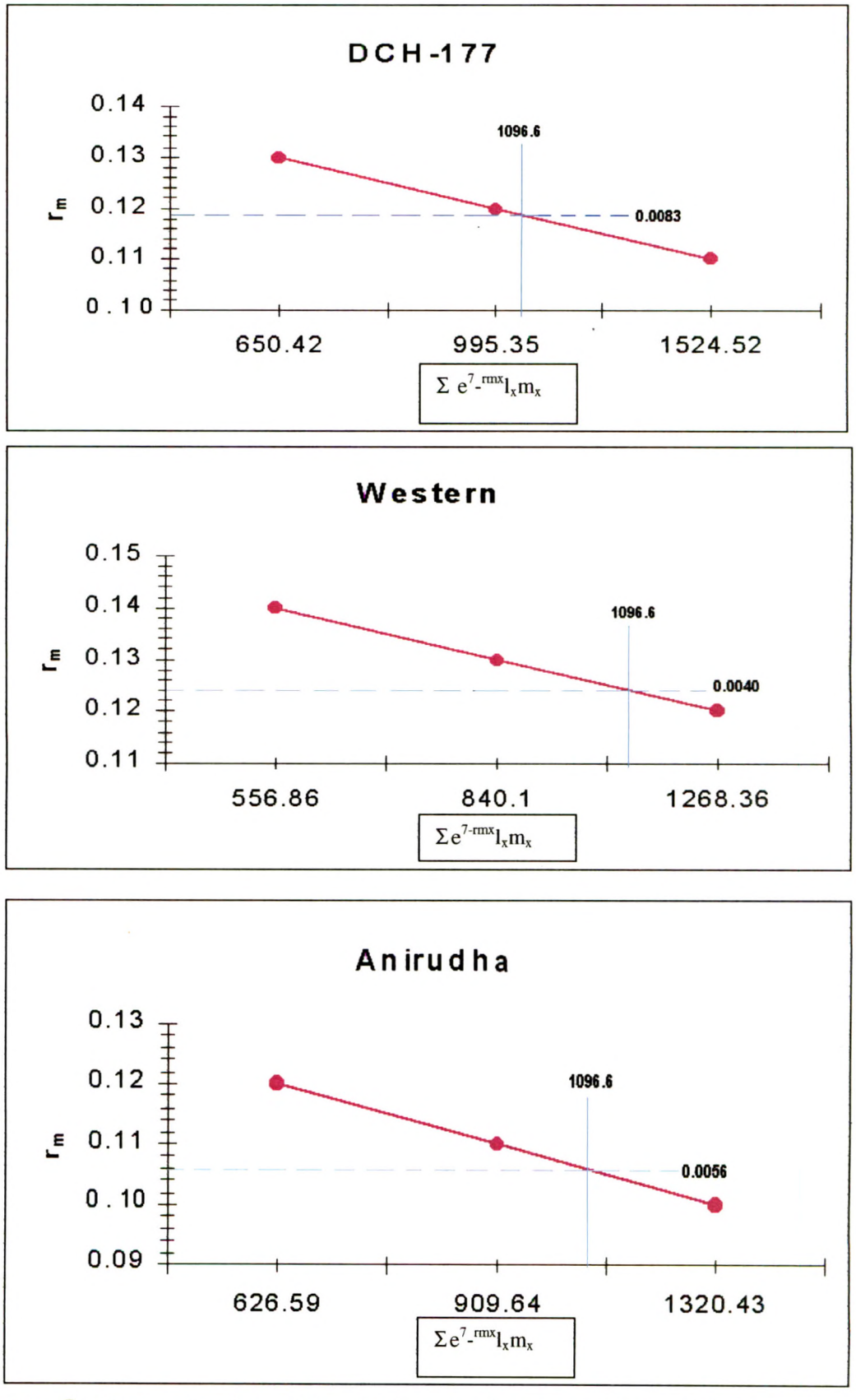


Fig .5: Determination of intrinsic rate of increase (r_m) of *A. janata* on different varieties of castor

Table 16 : Stable age-distribution of *A. janata* on DCH-177 when $r_m = 0.1183$.

Age group in days (x)	Survival of individuals at different age intervals (l_x)	Stable age-distribution $L_x = \left[\frac{l_x (l_x + 1)}{2}\right]$	$e^{-rm(x+1)}$	$L_x . e^{-rm(x+1)}$	Per cent distribution	
1	2	3	4	5	6	
0	1.00	1.00	0.8884	0.8884	15.7136	
1	1.00	0.92	0.7893	0.7379	13.0516	39.25
2	0.87	0.85	0.7012	0.5925	10.4798	Eggs
3	0.82	0.78	0.6230	0.4828	8.5395	
4	0.73	0.67	0.5534	0.3708	6.5585	
5	0.61	0.60	0.4917	0.2950	5.2178	
6	0.59	0.59	0.4369	0.2578	4.5998	
7	0.59	0.59	0.3881	0.2289	4.0487	
8	0.59	0.59	0.3448	0.2034	3.5976	
9	0.59	0.59	0.3063	0.1807	3.1961	
10	0.59	0.59	0.2722	0.1605	2.8388	
11	0.59	0.59	0.2418	0.1427	2.5240	54.27
12	0.59	0.59	0.2148	0.1267	2.2410	Larvae
13	0.59	0.59	0.1908	0.1125	1.9898	
14	0.59	0.59	0.1696	0.1001	1.7705	
15	0.59	0.59	0.1506	0.0889	1.5724	
16	0.59	0.59	0.1338	0.0789	1.3955	
17	0.59	0.59	0.1189	0.0702	1.2417	
18	0.59	0.59	0.1056	0.623	1.1019	
19	0.59	0.59	0.0939	0.0554	0.9794	
20	0.59	0.59	0.0834	0.0488	0.8631	
21	0.58	0.58	0.0741	0.0429	0.7588	2.03
22	0.58	0.58	0.0658	0.0382	0.6757	Pre-
23	0.58	0.58	0.0587	0.0338	0.5978	pupae
24	0.57	0.57	0.0519	00296	0.5236	
25	0.57	0.57	0.0462	0.0263	0.4652	
26	0.57	0.57	0.0410	0.0234	0.4139	
27	0.57	0.57	0.0364	0.0207	0.3661	3.55
28	0.57	0.57	0.0324	0.0185	0.3272	pupae

1	2	3	4	5	6	
29	0.57	0.57	0.0288	0.0164	0.2901	
30	0.57	0.57	0.0255	0.0145	0.2565	
31	0.57	0.57	0.0227	0.0129	0.2281	
32	0.57	0.57	0.0202	0.0115	0.2034	
33	0.57	0.57	0.0179	0.0102	0.1804	
34	0.57	0.56	0.0159	0.0089	0.1574	
35	0.55	0.55	0.0141	0.0078	0.1379	
36	0.55	0.55	0.0126	0.0069	0.1220	
37	0.55	0.55	0.0112	0.0062	0.1097	
38	0.55	0.55	0.0099	0.0054	0.0955	
39	0.55	0.55	0.0088	0.0048	0.0849	
40	0.55	0.55	0.0078	0.0043	0.0760	
41	0.55	0.55	0.0069	0.0038	0.0672	
42	0.55	0.55	0.0062	0.0034	0.0601	
43	0.55	0.55	0.0055	0.0030	0.0530	0.89
44	0.55	0.55	0.0049	0.0027	0.0478	Adults
45	0.55	0.55	0.0043	0.0230	0.0407	
46	0.54	0.54	0.0038	0.0021	0.0371	
47	0.54	0.53	0.0034	0.0018	0.0318	
48	0.52	0.50	0.0030	0.0015	0.0265	
49	0.47	0.46	0.0027	0.0012	0.0212	
50	0.45	0.45	0.0024	0.0011	0.0195	

It is evident from Table 16 that on reaching stable age-distribution, the population of *A. janata* on DCH-177 in its various stages viz., egg, larva, pre-pupa, pupa and adult distributed to the extent of 39.25, 54.27, 2.03, 3.55 and 0.89 per cent, respectively.

4.3.2 Life-fecundity tables of *A. janata* on Western

The data pertaining to life-tables and age-specific fecundity of *A. janata* on Western variety of castor are presented in Table 17 to 21.

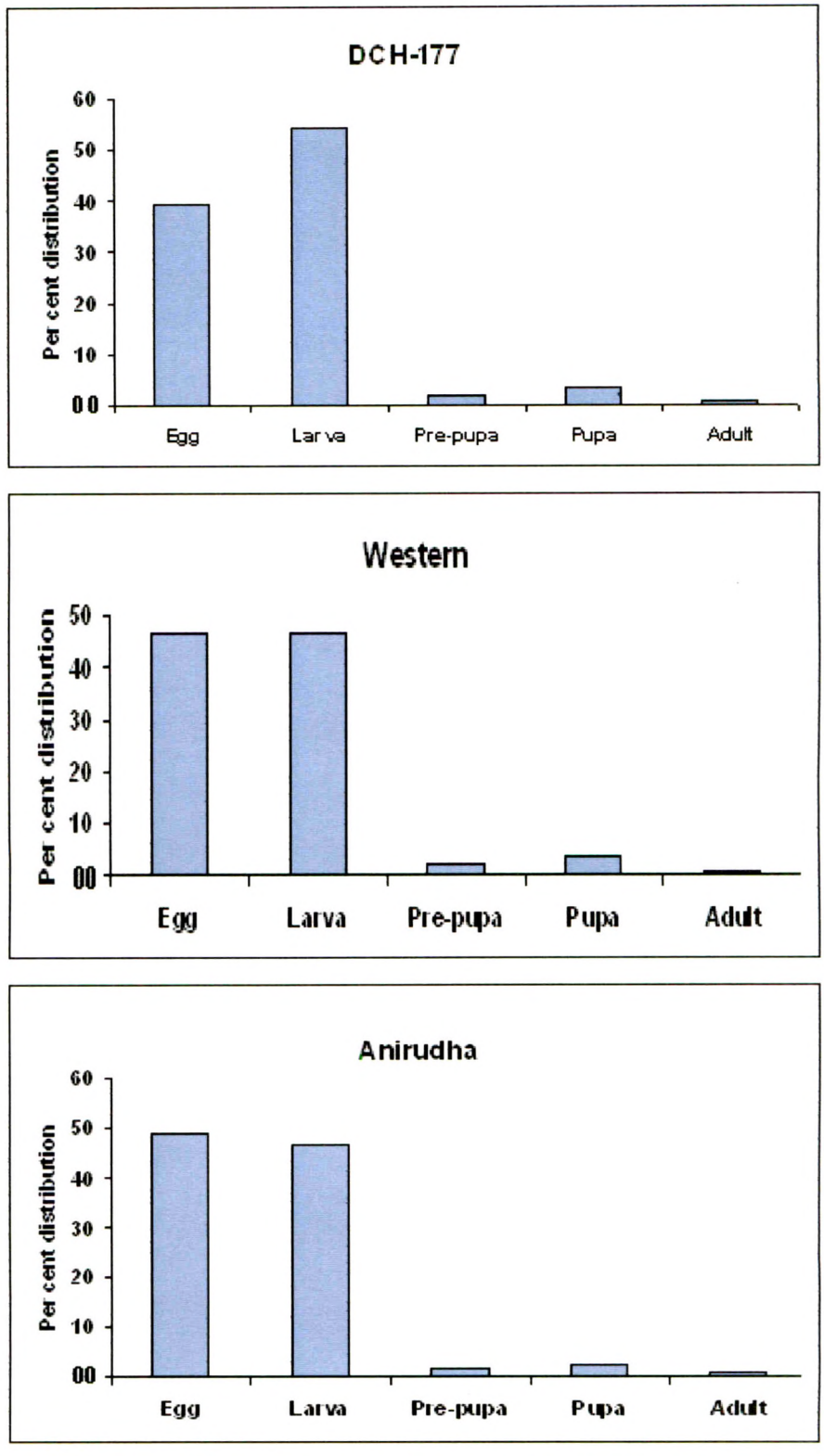


Fig. 6: Per cent individuals in stable age-distribution of *A. janata* on different varieties of castor

Table 17 : Survival of life stages of *A. janata* during development on Western.

Number of eggs observed	Number surviving					
	Egg duration (0-3 days)	Larval duration (4-19 days)	Pre-pupal duration (20-22 days)	Pupal duration (23-34 days)	Adult emergence	
					Male	Female
20	20	16	15	15	9	6
20	20	14	14	14	8	6
20	20	15	15	14	5	9
20	20	14	14	14	5	9
20	09	08	08	08	4	4
100	89	67	66	65	31	34

It is seen from Table 17 that the survival of *A. janata* was 89, 67, 66 and 65 per cent in respect of egg, larva, pre-pupa and pupa in a cohort of 100 eggs. There was emergence of 31 males and 34 females.

It is evident from Table 18 and Fig 4 that the survival of immature stages (l_x) was 0.65 per individual within a pivotal age of 34 days on Western. The pre-oviposition period ranged from 35th to 36th days of pivotal age. The highest female births (31.72) were observed at 42nd day of pivotal age. Thereafter female births fluctuated. The first female mortality was noticed on 6th day (l_x = 0.64) of oviposition when the culture was at the 42nd day of pivotal age. The females oviposited for 11 days. The net reproductive rate (R_o) representing the total female births was 172.39 females per female per generation.

Table 18 : Life-table and age-specific fecundity of *A. janata* on Western.

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
0-34	0.65	Immature stages		
35-36	0.65	Pre-oviposition period		
37	0.65	8.15	5.29	195.73
38	0.65	21.70	14.11	536.18
39	0.65	27.65	17.97	700.83
40	0.65	28.35	18.43	737.20
41	0.65	28.95	18.82	771.62
42	0.64	31.72	20.30	852.60
43	0.64	26.22	17.78	764.54
44	0.63	22.75	14.33	630.52
45	0.61	29.16	17.79	800.55
46	0.61	21.83	13.32	612.72
47	0.57	25.00	14.25	669.75
48	0.55	0.00	0.00	0.00
			Σl_xm_x= 172.39	Σl_xm_xX= 7272.24

The data in respect of mean length of generation, intrinsic rate of increase in numbers and finite rate of increase in numbers (λ) of *A. janata* on Western are given in Table 19.

Table 19 : Mean length of generation, innate capacity for increase in numbers and finite rate of increase in numbers of *A. janata* on Western.

Population growth statistics	
Mean length of generation $T_c = \frac{\Sigma l_x m_x X}{R_0}$	42.18 days
Innate capacity for increase in numbers $r_c = \frac{\text{Log}_e R_o}{T_c}$	0.1220 female/female/day
Arbitrary $r_m(r_c)$ 0.12, 0.13, 0.14 corrected r_m $\Sigma e^{7-rmx} l_x m_x$= 1096.6	0.1240 female/female/day
Corrected generation time $T = \frac{\text{Log}_e R_o}{r_m}$	41.53 days
Finite rate of increase in numbers (λ) λ = anti $\log_e r_m$	1.1320 Females/female/day

The mean length of generation (T_c) was found to be 42.18 days. The mean generation time (T) was 41.53 days. The innate capacity for increase in numbers (r_m) was 0.1240 female per female per day. The daily finite rate of increase in numbers (λ) was 1.1320 females per female per day.

Three trial values of 1268.36, 840.10 and 556.86 were plotted on horizontal axis against their respective arbitrary r_c i.e. 0.12, 0.13, 0.14 on vertical axis and corrected r_m was calculated by

interpolation method (Table 20). Thus, the corrected r_m was 0.1240 female per female per day (Fig.5).

Table 20 : Calculation of r_m by trial and error method on Western.

Pivotal age	$l_x m_x$	$r_m = 0.12$		$r_m = 0.13$		$r_m = 0.14$	
		$e^{(7-rmx)}$	$e^{(7-rmx)} l_x m_x$	$e^{(7-rmx)}$	$e^{(7-rmx)} l_x m_x$	$e^{(7-rmx)}$	$e^{(7-rmx)} l_x m_x$
37	5.29	12.94	68.43	8.94	47.27	6.17	32.65
38	14.11	11.47	161.88	7.85	110.70	5.37	75.71
39	17.97	10.18	182.86	6.89	123.80	4.66	83.82
40	18.43	9.02	166.33	6.05	111.49	4.06	74.74
41	18.82	8.00	150.64	5.31	99.97	3.53	66.35
42	20.30	7.09	144.11	4.66	94.69	3.06	62.21
43	17.78	6.29	111.95	4.09	72.83	2.66	47.37
44	14.33	5.58	80.02	3.59	51.54	2.32	33.19
45	17.79	4.95	88.11	3.16	56.18	2.01	35.82
46	13.32	4.39	58.51	2.77	36.93	1.75	23.32
47	14.25	3.89	55.52	2.43	34.70	1.52	21.68
48	0.00	3.46	0.00	2.14	0.00	1.32	0.00
Total		87.26	1268.36	57.88	840.10	38.43	556.86

The contribution made by different developmental stages towards stable age-distribution of *A. janata* on Western was determined and data are presented in Table 21 and Fig. 6.

Table 21 : Stable age-distribution of *A. janata* on Western when $r_m = 0.1240$.

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	0.8833	0.8833	14.4736	
1	1.00	1.00	0.7804	0.7804	12.7876	46.81
2	1.00	0.95	0.6894	0.6517	10.6754	Eggs
3	0.89	0.89	0.6089	0.5419	8.8795	
4	0.89	0.86	0.5379	0.4626	7.5801	
5	0.83	0.79	0.4752	0.3730	6.1119	
6	0.74	0.72	0.4198	0.3001	4.9174	
7	0.69	0.68	0.3708	0.2521	4.1309	
8	0.67	0.67	03276	02195	3.5967	
9	0.67	0.67	0.2894	0.1939	3.1772	
10	0.67	0.67	0.2556	0.1713	2.8069	
11	0.67	0.67	0.2258	0.1513	2.4792	
12	0.67	0.67	0.1995	0.1337	2.1907	46.60
13	0.67	0.67	0.1762	0.1180	1.9335	Larvae
14	0.67	0.67	0.1557	0.1043	1.7091	
15	0.67	0.67	0.1375	0.0921	1.5091	
16	0.67	0.67	0.1215	0.0814	1.3338	
17	0.67	0.67	0.1073	0.0719	1.1781	
18	0.67	0.67	0.0947	0.0634	1.0388	
19	0.67	0.67	0.0837	0.0557	0.9127	
20	0.66	0.66	0.0739	0.0488	0.8996	2.13
21	0.66	0.66	0.0653	0.0431	0.7062	Pre-
22	0.66	0.66	0.0557	0.0378	0.6194	pupae
23	0.65	0.65	0.0509	0.0330	0.5407	
24	0.65	0.65	0.0450	0.0293	0.4801	
25	0.65	0.65	0.0398	0.0259	0.4244	
26	0.65	0.65	0.0352	0.0229	0.3752	
27	0.65	0.65	0.0311	0.0202	0.3309	
28	0.65	0.65	0.0274	0.0178	0.2917	

1	2	3	4	5	6	
29	0.65	0.65	0.0242	0.0157	0.2572	3.60
30	0.65	0.65	0.0214	0.0139	0.2278	Pupae
31	0.65	0.65	0.0189	0.0123	0.2015	
32	0.65	0.65	0.0167	0.0109	0.1786	
33	0.65	0.65	0.0148	0.0096	0.1573	
34	0.65	0.65	0.0130	0.0085	0.1393	
35	0.65	0.65	0.0115	0.0075	0.1229	
36	0.65	0.65	0.0102	0.0066	0.1081	
37	0.65	0.65	0.0089	0.0058	0.0950	
38	0.65	0.65	0.0079	0.0051	0.0836	
39	0.65	0.65	0.0070	0.0046	0.0754	
40	0.65	0.65	0.0062	0.0040	0.0655	
41	0.65	0.65	0.0055	0.0035	0.0574	0.85
42	0.64	0.65	0.0048	0.0030	0.0492	Adults
43	0.64	0.64	0.0043	0.0027	0.0442	
44	0.63	0.62	0.0038	0.0024	0.0393	
45	0.61	0.61	0.0033	0.0020	0.0328	
46	0.61	0.59	0.0029	0.0017	0.0279	
47	0.57	0.56	0.0026	0.0015	0.0246	
48	0.55	0.55	0.0023	0.0013	0.0213	

The results presented in Table 21 revealed that on reaching stable age-distribution, the population of *A. janata* on Western in egg, larval, pre-pupal, pupal and adult stages contributed to the extent of 46.81, 46.60, 2.13, 3.60 and 0.85 per cent, respectively.

4.3.3 Life-fecundity tables of *A. janata* on Anirudha

The data in respect survival of life-stages of *A. janata* on Anirudha variety of castor are summarized in Table 22 to 26.

Table 22 : Survival of life stages of *A. janata* during development on Anirudha.

Number of eggs observed	Number surviving					
	Egg duration (0-3 days)	Larval duration (4-17 days)	Pre-pupal duration (18-20 days)	Pupal duration (21-31 days)	Adult emergence	
					Male	Female
20	15	4	4	3	2	1
20	16	4	3	3	1	2
20	14	6	6	6	1	5
20	15	6	6	6	3	3
20	13	5	5	5	4	1
100	73	25	24	23	11	12

The results presented in Table 22 revealed that *A. janata* survived to the extent of 73, 25, 24 and 23 per cent in egg, larval, pre-pupal and pupal stages, respectively in a cohort of 100 eggs. There was successful emergence of 11 males and 12 females on Anirudha.

It is clear from Table 23 and Fig. 4 that the survival of immature stages (l_x) was 0.23 per individual within a pivotal age of 31 days on Anirudha. The pre-oviposition period ranged from 32nd to 33rd days of pivotal age. The females contributed highest (m_x = 41.10) on 38th day of pivotal age. Thereafter the female births decreased gradually excepting at 42nd day of pivotal age. The first female mortality was observed on 40th day of pivotal age (l_x = 0.21) after that the female mortality increased slowly. The female laid eggs for 9 days. The net reproductive rate (R_o) representing total females per female per generation was 51.29. Thus the population of *A. janata* was able to multiply 51.29 times per generation on Anirudha.

Table 23 : Life-table and age-specific fecundity of *A. janata* on Anirudha.

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
0-31	0.23	Immature stages		
32-33	0.23	Pre-oviposition period		
34	0.23	11.10	2.55	86.70
35	0.23	24.10	5.54	193.90
36	0.23	32.55	7.49	269.64
37	0.23	36.60	8.42	311.54
38	0.23	41.10	9.95	359.24
39	0.23	32.60	7.49	292.11
40	0.21	22.68	4.76	190.40
41	0.20	15.35	3.07	125.87
42	0.14	18.00	2.52	105.84
43	0.13	0.00	0.00	0.00
			ΣI_xm_x= 51.29	ΣI_xm_xX= 1935.24

The data pertaining to mean length of generation intrinsic rate of increase in numbers and finite rate of increase in numbers (λ) of *A. janata* on Anirudha are presented in Table 24.

Table 24 : Mean length of generation, innate capacity for increase in numbers and finite rate of increase in numbers of *A. janata* on Anirudha.

Population growth statistics	
Mean length of generation $T_c = \frac{\Sigma l_x m_x X}{R_0}$	37.73 days
Innate capacity for increase in numbers $r_c = \frac{\text{Log}_e R_o}{T_c}$	0.1043 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	0.1056 female/female/day
Corrected generation time $T = \frac{\text{Log}_e R_o}{r_m}$	37.29 days
Finite rate of increase in numbers (λ) λ = anti $\log_e r_m$	1.1113 females/female/day

It is evident from Table 24 that the mean length of generation (T_c) was 37.73 days. The arbitrary value for intrinsic rate of natural increase (r_c) was 0.1043 female per female per day. The mean generation time (T) was 37.29 days, while finite rate of increase in numbers (λ) was 1.1113 females per female per day.

Three trial values of 1320.43, 909.64 and 626.59 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 (Table 25). The corrected r_m was 0.1056 female per female per day (Fig. 5).

Table 25 : Calculation of r_m by trial and error method on Anirudha.

Pivotal age	$l_x m_x$	$r_m = 0.10$		$r_m = 0.11$		$r_m = 0.12$	
		$e^{(7-rmx)}$	$e^{(7-rmx)} l_x m_x$	$e^{(7-rmx)}$	$e^{(7-rmx)} l_x m_x$	$e^{(7-rmx)}$	$e^{(7-rmx)} l_x m_x$
34	2.55	36.59	93.33	26.05	66.43	18.54	47.28
35	5.54	33.11	183.45	23.34	129.28	16.44	91.10
36	7.49	29.96	224.43	20.91	156.58	14.59	109.24
37	8.42	27.11	228.29	18.72	157.69	12.94	108.92
38	9.45	24.53	231.23	16.78	158.54	11.47	108.42
39	7.49	22.19	166.26	15.03	112.57	10.18	76.22
40	4.76	20.09	95.61	13.46	64.09	9.03	42.95
41	3.07	18.17	55.79	12.06	37.23	8.00	24.57
42	2.52	16.44	41.44	10.80	27.23	7.09	17.89
43	0.00	14.87	0.00	9.67	0.00	9.29	0.00
Total		243.06	1320.43	166.82	909.64	114.57	626.59

The stable age-distribution of *A. janata* on Anirudha was determined and the data are presented in Table 26 and Fig. 6.

Table 26 : Stable age-distribution of *A. janata* on Anirudha when $r_m = 0.1056$.

Age group in days (x)	Survival of individuals at different age intervals (l_x)	Stable age-distribution $L_x = \frac{l_x (l_x + 1)}{2}$	$e^{-rm(x+1)}$	$L_x \cdot e^{-rm(x+1)}$	Per cent distribution	
1	2	3	4	5	6	
0	1.00	1.00	0.8998	0.8998	15.6074	
1	1.00	1.00	0.8096	0.8096	14.0429	48.81
2	1.00	0.86	0.7285	0.6265	10.8669	Eggs
3	0.73	0.73	0.6555	0.4785	8.2998	
4	0.73	0.73	0.5898	0.4306	7.4689	
5	0.73	0.73	0.5307	0.3874	6.7196	
6	0.73	0.69	0.4775	0.3319	5.7569	
7	0.66	0.64	0.4296	0.2771	4.8064	
8	0.63	0.61	0.3866	0.2389	4.1438	
9	0.60	0.57	0.3478	0.1999	3.4674	
10	0.55	0.54	0.3129	0.1705	2.9574	46.22
11	0.54	0.54	0.2816	0.1521	2.6382	Larvae
12	0.54	0.54	0.2534	0.1368	2.3729	
13	0.54	0.50	0.2280	0.1140	1.9774	
14	0.46	0.41	0.2052	0.0852	1.4778	
15	0.37	0.32	0.1846	0.0599	1.0389	
16	0.28	0.26	0.1661	0.0440	0.7632	
17	0.25	0.24	0.1494	0.0366	0.6348	
18	0.24	0.23	0.1345	0.0316	0.5481	1.46
19	0.23	0.23	0.1209	0.0278	0.4822	Pre-
20	0.23	0.23	0.1089	0.0250	0.4336	pupae
21	0.23	0.23	0.0979	0.0225	0.3902	
22	0.23	0.23	0.0881	0.0203	0.3521	
23	0.23	0.23	0.0793	0.0182	0.3157	
24	0.23	0.23	0.0714	0.0164	0.2845	
25	0.23	0.23	0.0642	0.0148	0.2567	2.68
26	0.23	0.23	0.0578	0.0133	0.2307	Pupae
27	0.23	0.23	0.0519	0.0119	0.2064	
28	0.23	0.23	0.0468	0.0108	0.1873	

1	2	3	4	5	6	
29	0.23	0.23	0.0420	0.0097	0.1683	
30	0.23	0.23	0.0379	0.0087	0.1509	
31	0.23	0.23	0.0341	0.0078	0.1353	
32	0.23	0.23	0.0307	0.0071	0.1232	
33	0.23	0.23	0.0276	0.0063	0.1093	
34	0.23	0.23	0.0248	0.0057	0.0989	
35	0.23	0.23	0.0223	0.0051	0.0885	
36	0.23	0.23	0.0200	0.0046	0.0798	
37	0.23	0.23	0.0180	0.0041	0.0711	0.82
38	0.23	0.23	0.0163	0.0037	0.0642	Adults
39	0.23	0.22	0.0146	0.0032	0.0555	
40	0.21	0.20	0.0131	0.0027	0.0468	
41	0.20	0.17	0.0118	0.0020	0.0347	
42	0.14	0.13	0.0107	0.0014	0.0243	
43	0.13	0.13	0.0096	0.0012	0.0208	

It is evident from Table 26 that on reaching stable age-distribution, the population of *A. janata* on Anirudha in egg, larva, pre-pupa, pupa and adult stage distributed to the extent of 48.81, 46.22, 1.46, 2.68 and 0.82 per cent, respectively.

DISCUSSION

Chapter V

DISCUSSION

The results obtained in the present investigation on growth and development of *Achaea janata* Linnaeous on different varieties of castor are discussed in this chapter in the light of available literature under the following headings.

5.1 Biology

5.2 Biometrical studies

5.3 Life-fecundity tables

5.4 Overall suitability of castor varieties

5.1 Biology

The mean egg period of *A. janata* on DCH-177, Western and Anirudha varieties of castor varied from 1.87 and 3.00 days (Table 1). These results are in conformity with that of Khan (1946), Smee (1962), Srivastava and Pande (1966) and Byale and Bilapate (1990) who reported the incubation period to the extent of 2 to 3, 3, 2 to 4 and 2.02 to 3 days, respectively.

The significantly shortest mean larval duration to the tune of 11.79 days was observed on Western followed by Anirudha (12.79 days) and DCH-177 (13.65 days) (Table 1). On the basis of larval duration the preference of food plants could be arranged as Western, Anirudha and DCH-177. The present findings in respect of larval duration are similar to that of the results reported by Khan (1946), Smee (1962), Ramdev and Rao (1979), Islam and Narsin (1986), Karmavati and Tobing (1988) and Byale and Bilapate (1990). According to them the larval duration was 12 to 13, 11 to 17, 8 to 12, 13 to 19, 9 to 13 and 12.38 days, respectively.

The significantly highest growth index was observed on those larvae, which were fed on the leaves of Western (5.56) followed by DCH-177 (4.22) and Anirudha (1.79). This indicates that Western variety of castor is preferred more by *A. janata* than DCH-177 and Anirudha. The similar trend was also observed in the case of percent pupation (Table 1).

The shortest pre-pupal and pupal duration to the extent of 1.71 and 9.57 days was observed on DCH-177 and Western varieties of castor, respectively (Table 2). The order of suitability of varieties of castor based on pupal duration was Western, DCH-177 and Anirudha. Smee (1962), Pandey *et al.* (1967), Islam and Narsin (1986) and Karmavati and Tobing (1988) observed pupal duration to the extent of 9 to 14, 7 to 26, 9 to 12 and 8 to 10 days, respectively. The findings pertaining to pupal duration are in good agreement with the earlier workers. The significantly lowest per cent adult emergence was observed in the case of larvae which were reared on Anirudha (23 per cent) followed by DCH-177 (55 per cent) and Western (65 per cent) (Table 2).

The mean general life cycle duration of *A.janata* was observed to be significantly highest (29.24 days) on Anirudha followed by DCH-177 (28.47 days) and Western (27.01 days). However, significantly highest mean life cycle duration of male and female to the extent of 29.65 and 29.16 days, respectively was recorded on Anirudha followed by DCH-177 (28.72 and 27.90 days) and Western (27.14 and 26.89 days) (Table 2). According to Khan (1946) and Pandey (1967) the life cycle of *A. janata* was completed in 28 and 30 days on castor, respectively. While Tahiliani (1985) reported the life cycle of *A. janata* to the extent of 29 to 35 days on castor in Gujarat during September –

November. These results are in good agreement with the present studies on life cycle duration of *A. janata* on different varieties of castor.

The pupal measurements were made for its length, width and weight when larvae reared on different varieties of castor. However, statistically significant differences were not observed in the case of pupal length and width of both the sexes and in general excepting general pupal length. The pupal length of male, female and in general varied from 22.73 to 22.99, 22.58 to 24.20 and 22.64 to 23.59 mm, respectively. The corresponding values for pupal width ranged from 11.82 to 12.32, 12.06 to 12.30 and 12.02 to 12.26 mm. Significantly highest pupal weight to the extent of 880, 910 and 890 mg was observed in the case of general, male and female *A. janata*, respectively when reared on Anirudha variety of castor followed by DCH-177 (830, 830 and 840 mg) and Western (780, 780 and 790 mg). On the basis of pupal weight the food plants could be arranged in descending order as Anirudha, DCH-177 and Western.

Srivastava and Pande (1966) observed average length and breadth of male and female pupae of *A. janata* to the extent of 2.1, 6.3 and 2.3, 0.7 cm, respectively. The present findings in respect of pupal length are in line with that of Srivastava and Pande (1966).

The significantly lowest pre-oviposition period (2.50 days) was recorded on Western variety of castor followed by Anirudha (2.90 days) and DCH-177 (3.00 days) (Table 4). Byale and Bilapate (1990) also reported 3 days of pre-oviposition period of *A. janata* on castor. The significantly highest oviposition period (10.70 days) was observed on DCH-177 followed by Western (9.00 days) and Anirudha (7.70 days) (Table 4). Srivastava and Pande (1966), Pandey *et al.* (1967)

and Bilapate (1987) observed 2 to 7, 2 to 11 and 7 days of oviposition period of *A. janata* on castor leaves, respectively. The significantly highest number of eggs to the tune of 526.40 per female were laid by the female moths which were emerged from the larvae reared on the leaves of DCH-177 variety of castor followed by Western (441.50) and Anirudha (417.50) (Table 4). On the basis of fecundity it seems that DCH-177 is preffered more by *A. janata* than Western and Anirudha varieties of castor. The egg laying capacity to the tune of 577 and 467 eggs were reported by Koshiya *et al.* (1986) and Byale and Bilapate (1987), respectively. The results in respect of pre-oviposition, oviposition and fecundity are in pursuant to the findings of above mentioned earlier research workers.

5.2 Biometrical studies

The biometrical studies were made by measuring head capsule width and body length and width of larvae of different instars of *A. janata* on DCH-177 and Western varieties of castor under laboratory conditions. The biometrical studies of *A. janata* on Anirudha variety of castor were not carried out for want of its sufficient culture. According to Dyar (1890), the head capsule width of any lepidopterous larvae is more or less constant for any instar of given species. Also the successive larval instars of given species show more or less regular geometrical progression in the growth of head capsule. He also described that the growth ratio of the mean head capsule width of each instar and that of the preceding one indicate growth directly i.e. greater the ratio, greater the growth. The ratio is also known as Dyar's ratio.

The results revealed that the larvae of *A. janata* when reared on DCH-177 and Western varieties of castor passed through five instars.

The similar number of larval instars on leaves of castor was reported by Srivastava and Pande (1966), Pandey *et al.* (1967) and Byale and Bilapate (1987). The duration of I to V instar was 3, 2, 3, 3 and 5 days, respectively on DCH-177 and 3, 3, 2, 4 and 5 days, respectively on Western (Table 11). Comparatively the instar duration for all five instars was more or less same on DCH-177 and Western. According to Srivastava and Pande (1966) the range of larval duration for I, II, III, IV and V instar was 2, 1 to 3, 2 to 3, 2 to 5 and 4 to 6 days, respectively.

The larval head capsule width was found to be 0.37, 0.91, 1.50, 2.70 and 3.91 mm on DCH-177 and 0.50, 0.96, 1.55, 2.72 and 3.50 mm on Western for I to V instars, respectively. The observed progression factors for head capsule width on DCH-177 and Western were 1.79 and 1.65, respectively (Table 5 and 6). Byale and Bilapate (1990) measured larval head capsule width to the extent of 0.390, 0.706, 1.162, 1.898 and 2.769 mm for I to V instars, respectively. The calculated values of larval head capsule width of respective instars on DCH-177 and Western were more or less similar to that of observed values.

Comparatively high growth ratios were often encountered in the early part of larval development and there was a tendency for the growth ratios to diminish during larval development. It seems from the literature that the cases of diminishing ratios are usual rather than unusual (Taylor, 1931 and Gaines and Campbell, 1935). The observed progression factors for head capsule width on DCH-177 and Western were 1.79 and 1.65, respectively (Table 5 and 6).

When log of head capsule width were plotted in relation to different instars of *A. janata* fed on DCH-177 and Western varieties of

castor, a definite geometrical relationship was observed for all the instars on tested varieties as derived by Dyar (1890).

The mean observed body length of larva on DCH-177 for I, II, III, IV and V instars was 2.61, 7.33, 16.28, 27.31 and 43.18 mm, respectively. The corresponding values on Western were 2.80, 8.04, 16.68, 27.41 and 40.26 mm, respectively. The observed progression factors for body length of larva on DCH-177 and Western were 2.07 and 2.01, respectively (Table 7 and 8).

The mean observed body width of larva on DCH-177 was 0.25, 0.84, 1.68, 2.81 and 3.63 mm for I to V instars, respectively. The corresponding values on Western were 0.44, 0.98, 1.71, 2.86 and 3.40 mm, respectively. The observed progression factors for body width of larva on DCH-177 and Western were 2.08 and 1.71, respectively (Table 9 and 10).

5.3 Life-fecundity tables

The qualitative and quantitative evaluation of different host plants can be made by using life-tables of insect-pests. In the present investigations, the projected potential rate of increase of *A. janata* on different varieties of castor was computed by following the method described by Birch (1948), Howe (1953) and Atwal and Bains (1974). The results obtained in the present investigations are discussed in the light of available literature on *A. janata* and other insects.

The survival of immature stages (lx) was 0.55,0.65 and 0.23 per individual within a pivotal age of 35, 34 and 31 days on DCH-177 Western and Anirudha respectively. The net reproductive rate (R_o) of *A. janata* was 155.87 on DCH-177, 172.39 on Western and 51.29 females per female per generation on Anirudha (Table 13, 18 and 23). According to Byale and Bilapate (1987), the net reproductive rate (R_o) was 467.57

females per female per generation on castor leaves. The net reproductive rate (R_o) representing the total female births was 577.49 (Koshiya *et al.*, 1986). The net reproductive rate of *A. janata* on castor leaves was 524.75, 382.52 and 242.70 females per female during I, II and III generations respectively under laboratory conditions (Bilapate, 1987). According to Gaikwad and Bilapate (1993) the net reproductive rate of *A. janata* was 325.94 on castor.

In general, the values of net reproductive rates reported by earlier workers on castor leaves are little higher than those observed in the present study. The differences might have attributed because of effect of meteorological parameters during rearing. Secondly it may also be due to varietal differences.

The mean length of generation time (T) differed considerably on different varieties of castor. It was maximum (42.68 days) on DCH-177 followed by 41.53 days on Western and 37.29 days on Anirudha. The innate capacity for increase in numbers (r_m) varied from 0.1056 to 0.1240 female per female per day (Table 14, 19 and 24). Based on 'r_m' values the descending order of food plants for *A. janata* was Western (0.1240), DCH-177 (0.1183) and Anirudha (0.1056). The finite rates of increase in numbers (λ) were 1.1320, 1.1255 and 1.1113 females per female per day on Western, DCH-177 and Anirudha, respectively.

The distribution of egg stage in the stable age-distribution was 39.25, 46.81 and 48.81 per cent on DCH-177, Western and Anirudha, respectively. The contribution of larval stage to stable age-distribution was 54.27, 46.60 and 46.22 per cent on DCH-177, Western and Anirudha, respectively (Table 16, 21 and 26).

According to Birch (1948), the comparison of two or more population by means of their net reproductive rates may be quite misleading unless the mean length of generation are the same. Two or more populations may have the same reproductive rate but their intrinsic rates of increase may be quite different because of different length of their generations.

It is evident that on the basis of net reproductive rates (R_o), innate capacity for increase in numbers (r_m) and mean generation time (T), Western occupied first position followed by DCH-177 as well as Anirudha.

The life-tables giving the statistics on (r_m) of particular species provide insight into characteristics life patterns of different species (Birch, 1948). The application of these statistics is as diverse as the insects for which the life-tables are developed. From the point of view of pest multiplication, Western variety of castor with high 'r_m' value would be the most suitable. The castor semilooper, *A. janata* would multiply 172.39 times per generation on Western, while the corresponding increase was 155.87 times on DCH-177 and 51.29 times on Anirudha. This indicates that the population would increase by more than 3 fold on Western as compared to Anirudha.

According to Byale and Bilapate (1987), the mean generation time (T) was 37.99 days and the intrinsic rate of natural increase (r_m) was 0.1618 female per female per day. On reaching the stable age-distribution the population of *A. janata* on castor in its various stages viz., egg, larva, pupa and adult contributed to the extent of 49.06, 48.06, 2.50 and 0.34 per cent, respectively.

The innate capacity for increase in numbers (r_m) and mean generation time (T) was 0.1692 and 37.01 days during first generation on castor leaves (Bilapate, 1987). According to Koshiya *et al.* (1986), the mean duration of a generation (T) was 42.44 days. The intrinsic rate of natural increase (r_m) was 0.1498 with 1.26 daily finite rate of increase in numbers (λ). The present findings pertaining to mean generation time (T) and stable age-distribution of *A. janata* on castor are in line with the data reported by Koshiya *et al.* (1986), Bilapate (1987) and Byale and Bilapate (1987).

Bilapate *et al.* (1977), Bilapate and Pawar (1978) and Dandapani and Balsubramanian (1979) also conducted similar studies on life-fecundity tables of *H. armigera* and other lepidopterous pests.

5.4 Over all suitability of castor varieties

An attempt was made to understand the overall order of suitability of different varieties of castor for *A. janata.* In all 17 characters including aspects on biometrical studies, biology and life-fecundity tables were considered. The varieties were arranged for each character and scored by giving ten points for first position and reducing one point for each subsequent position. The total score for each variety was considered in arranging them in the order of suitability. The varieties were arranged in ascending order for characters like larval duration, pupal duration, life-cycle, pre-oviposition period, pivotal age for immature stages and generation time (T), while for the characters like per cent larvae pupated, pupal length, width and weight, growth index, per cent adult emergence, oviposition period, fecundity, survival of immature

stages (l_x), net reproductive rate (R_o) and innate capacity for increase in numbers (r_m) they were arranged in descending order (Appendix I). The charaters like head capsule width, and larval body length and width were not taken into account for the determination of overall suitability of different varieties of castor under investigation. Because these three characters were not studied on Anirudha variety of castor for want of sufficient culture.

Thus, the overall order of suitability of varieties of castor tested in descending order with the respective total points obtained was Western (161), DCH-177 (151) and Anirudha (147). Similar attempts were also made by Bilapate (1978) and Gaikwad (1988) to understand the overall order of suitability of host plants for *A. janata* and *H. armigera*, respectively.

On the basis of the data on overall suitability of varieties of castor for *A. janata* under investigation it can be concluded that Western variety of castor is most suitable for *A. janata* as compared to DCH-177 and Anirudha for multiplication of its population. This data can be very well utilized in the pest management programme.

SUMMARY

Chapter VI

SUMMARY

The laboratory experiments were carried out to study the growth and development of *Achaea janata* on different varieties of castor at the department of Entomology, College of Agriculture, Latur during 2004-2005. Studies on biology and life-fecundity tables of *A. janata* were conducted on DCH-177, Western and Anirudha varieties of castor. However, biometrical studies were carried out on DCH-177 and Western. The completely randomized design was used to study the biology of *A. janata.*

6.1 The mean incubation period of *A. janata* varied from 1.87 to 3.00 days on different varieties of castor. The significantly shortest larval duration (11.79 days), the highest growth index (5.56) and the highest percent pupation was observed in the case of those larvae which were fed on Western variety of castor. The shortest pre-pupal and pupal duration to the extent of 1.71 and 9.57 days were recorded on DCH-177 and Western, respectively. The significantly highest general pupal length (23.59 mm) was recorded on Anirudha. The significantly highest pupal weight to the tune of 880, 910 and 890 mg was observed in the case of general, male and female *A. janata,* respectively when larvae were fed on Anirudha. The lowest adult emergence to the tune of 23 per cent was observed on Anirudha. The significantly highest life cycle duration to the extent of 29.24, 29.65 and 29.16 days was observed in the case of general, male and female, respectively when larvae were reared on Anirudha variety of castor. The significantly lowest pre-oviposition (2.50 days) and highest oviposition period (10.70 days) were recorded on Western and DCH-177, respectively. Significantly highest number of

eggs (526.40) per female were laid by female moths which were emerged from the larvae fed on the leaves of DCH-177.

6.2 The mean measurements of head capsule width, larval body length and width of *A. janata* on DCH-177 were 0.37, 0.91, 1.50, 2.70 and 3.91 mm, 2.61, 7.33, 16.28, 27.31 and 43.18 mm and 0.25, 0.84, 1.68, 2.81 and 3.63 mm for I, II, III, IV and V instar, respectively. The corresponding values on Western were 0.50, 0.96, 1.55, 2.72 and 3.50 mm, 2.80, 8.04, 16.68, 27.41 and 40.26 mm and 0.44, 0.98, 1.71, 2.86 and 3.40 mm. The observed progression factors for larval head capsule width and body length and width on DCH-177 were 1.79, 2.07 and 2.08, respectively. The corresponding values on Western were 1.65, 2.01 and 1.71. The larvae of *A. janata* passed through five instars on each of the castor varieties tested under investigation.

6.3 The survival of immature stages (l_x) was 0.55, 0.65 and 0.23 per individual within a pivotal age of 35, 34 and 31 days on DCH-177, Western and Anirudha, respectively. The population of *A. janata* was able to multiply 155.87, 172.39 and 51.29 times per generation on DCH-177, Western and Anirudha varieties of castor, respectively. The mean length of generation and precise generation time (T) of *A. janata* on DCH-177, Western and Anirudha were 43.37 and 42.68, 42.18 and 41.53 and 37.73 and 37.29 days, respectively. The intrinsic rate of natural increase (r_c) was 0.1164, 0.1220 and 0.1043 female per female per day on DCH-177, Western and Anirudha, respectively. The corrected innate capacity for increase in numbers (r_m) was 0.1183, 0.1240 and 0.1056 female per female per day on DCH-177, Western and Anirudha, respectively. The finite rate of increase in numbers (λ) was 1.1255

females per female per day on DCH-177. The corresponding values on Western and Anirudha were 1.1320 and 1.1113, respectively. On reaching stable age-distribution the population of *A. janata* on DCH-177 in egg, larva, pre-pupa, pupa and adult stage contributed to the extent of 39.25, 54.28, 2.03, 3.55 and 0.89 per cent, respectively. The corresponding figures on Western and Anirudha were 46.81, 46.60, 2.13, 3.60 and 0.85 and 48.81, 46.22, 1.46, 2.68 and 0.82, respectively.

6.4 The variety viz.,Western recorded the highest (166) score of overall order of suitability followed by DCH-177 (151) and Anirudha (147). This indicates that Western variety of castor was found to be most suitable for the growth and development of *A. janata* as compared to other varieties tested under investigation.

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*Originals not seen

APPENDIX

APPENDIX I

The relative score of different parameters for growth and development of *A. janata* on different varieties of castor

Sr. No.	Characters	Varieties of castor		
		DCH-177	Western	Anirudha
1.	Larval duration	8	10	9
2.	Per cent larvae pupated	9	10	8
3.	Growth index	9	10	8
4.	Pupal duration	9	10	8
5.	Pupal length	8	9	10
6.	Pupal width	10	8	9
7.	Pupal weight	9	8	10
8.	Per cent adult emergence	9	10	8
9.	Life cycle duration	9	10	8
10.	Pre-oviposition period	8	10	9
11.	Oviposition period	10	9	8
12.	Fecundity	10	9	8
13.	Pivotal age for immature stage	8	9	10
14.	l_x	9	10	8
15.	R_o	9	10	8
16.	r_m	9	10	8
17.	T	8	9	10
	Total score	151	161	147

APPENDIX II

Weekwise meteorological data during the period of investigation

Year : 2004 Latitude : 18^0 24'N
State : Maharashtra Longitude : 76^0 36'
Location : Latur Altitude : 633.85 m.

Month	Std. Met. week No.	Mean Temp. (^{0}C)		Rainfall (mm)	No. of rainy days	Relative humidity (%)	
		Min.	Max.			Min.	Max.
1	2	3	4	5	6	7	8
Aug. 04	32	22.2	29.7	19.0	2	72.4	83.4
	33	22.9	29.1	8.0	1	59.6	67.7
	34	21.6	28.9	21.1	2	73.0	82.0
	35	21.9	29.5	-	-	76.3	86.9
Sept. 04	36	21.5	28.9	49.5	1	79.1	72.7
	37	22.4	29.6	63.5	2	53.0	53.0
	38	23.1	30.6	35.5	2	71.0	91.0
	39	22.4	30.3	123.5	3	76.4	77.3
Oct. 04	40	22.4	31.3	47.5	3	73.7	73.8
	41	21.8	32.4	32.6	2	70.6	75.9
	42	23.1	33.1	-	-	65.0	72.0
	43	21.6	32.6	-	-	64.3	70.0
	44	20.2	30.1	4.0	-	62.3	69.3
Nov.04	45	19.9	28.8	34.0	1	61.0	64.0
	46	19.7	28.5	-	-	60.1	72.3
	47	17.6	28.1	-	-	66.4	71.3
	48	17.1	27.5	-	-	63.9	69.7
Dec. 04	49	10.8	27.0	-	-	62.6	78.1
	50	11.0	27.3	-	-	62.6	80.9
	51	11.1	27.4	-	-	62.0	77.3
	52	10.8	27.7	-	-	58.9	73.5