

**BIO – ECOLOGICAL STUDIES OF
CASTOR SEMILOOPER, *Achaea janata* LINNAEUS**

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M.Sc. (Agri.)

T 1533



A DISSERTATION
SUBMITTED TO THE MARATHWADA AGRICULTURAL UNIVERSITY
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FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
IN AGRICULTURAL ENTOMOLOGY

DEPARTMENT OF ENTOMOLOGY
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PARBHANI

1988

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GAI

AFFECTIONATELY DEDICATED TO MY BELOVED
GRAND FATHER AND GRAND MOTHER
LATE HARIBHAU AND KRISHNA GAIKWAD

BIO-ECOLOGICAL STUDIES OF CASTOR SEMILOOPER, ACHAEA
JANATA LINNAEUS

By

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DOCTOR OF PHILOSOPHY

in

AGRICULTURAL ENTOMOLOGY

T 1533

Department of Entomology,
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Parbhani

1988

CANDIDATE'S DECLARATION

**I hereby declare that this dissertation or a
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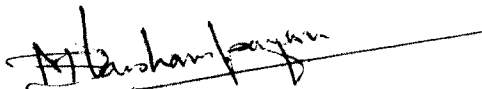

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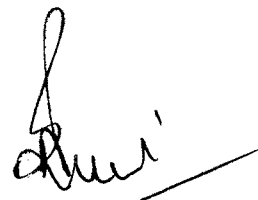
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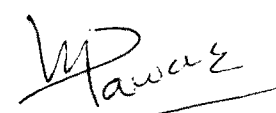
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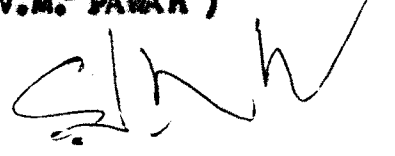

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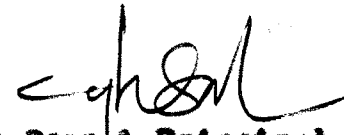

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I. INTRODUCTION

I. INTRODUCTION

Castor, Ricinus communis Linnaeus is one of the important oilseed crops in Maharashtra. It is grown in Africa, Brazil, U.S.A., Egypt, Sudan and many of the Asian countries including India (Watt, 1982). Castor oil is used for the production of high grade lubricating oils, paints, varnishes, vulcanising substances, glycerine, hydraulic fluids, cosmetic soaps, printing ink and linoleum. It also serves as raw material in the manufacture of various important chemicals such as sebacic acid for the manufacture of nylon. Raw castor oil is believed to have a growth promoting effect on hairs, hence used in perfume hair oils. Owing to its laxative property, it is also used as medicine. The oil cake has vermifugal properties and is used as manure especially in fields attacked by white ants. The castor stalks can be used for the manufacture of paper pulp for production of writing, printing and wrapping papers (Patel, 1963). Considering its vast use, recently the castor is being cultivated on large scale in India.

India ranks second in the world in respect of castor seed production. The major castor growing states in India are Andhra Pradesh, Gujarat, Karnataka, Tamil Nadu, Maharashtra and Rajasthan which contribute maximum to castor production in India (Kutumba et al., 1960:

Kundu et al., 1966). The acreage and production of castor in India and Maharashtra during 1985-86 was 63.71, 406.8 and 5.6, 2.6 thousand hectares and thousand tonnes, respectively (Anonymous, 1985).

Among many factors responsible for low yields, attack of insect pests is major one. Castor is attacked by 61 different kinds of insect pests in India. The most important pests are castor semilooper, Achaea janata Linnaeus, castor shoot and capsule borer, Dichocrocis punctiferalis (Guene), tobacco caterpillar, Spodoptera litura (F), castor jassids, Empoasca flavescens (Fab), white fly, Trialeurodes ricini Mishra and Red spider mite, Tetranychus telarius Linn. (Vora et al., 1984).

The castor semilooper Achaea janata Linnaeus (Noctuidae : Lepidoptera) is a serious pest of castor in many castor growing states of India. The larvae of A. janata L. soon after hatching nibble only the outer tissues of the leaf. The second instar caterpillars damage the leaves by making holes, the third and fourth instar caterpillars completely defoliate the leaves. In case of severe infestation, entire castor fields are defoliated and some times the larvae feed on stems as well (Khan, 1946; Kundu et al., 1966; Srivastava and Pande, 1966; Tahiliani, 1985).

The adult moth of A. janata L. has been reported as a ^rfruit sucking moth on ripening fruits of

citrus, guava, pomegranate and grape. During night hours, moths damage the ripened fruits with proboscis and suck the fruit juice. The damaged fruits are pierced for a number of times and several holes are made on rind. Such infested fruits rot very rapidly, drop down and reduce the yield to a greater extent (Bhattacharjee, 1968; Rakshpal, 1945; Srivastava and Pande, 1966; Pandey and Sukhani, 1965 and Butani, 1972).

During the past decade the severity of attack by *A. janata* on fairly large number of cultivated crops appears to have increased. It is well documented fact that, the food plants play a vital role in survival and reproductive potential of the insects. The species of variety of plants vary in their physical or chemical constituents which in turn may render them susceptible or resistant to insect pest attack. The plant characters, which interfere with the normal physiology or feeding of the insects on them, affect adversely the biology of the pest (Painter, 1951).

Little studies on biology and bio-metrics of *A. janata* have been reported from different states in India (Khan, 1966; Singh, 1965; Srivastava and Pande, 1966; Pandey, 1967, Byala and Bilapate, 1967). Though there is considerable literature available on the aspects of chemical control, however scanty information is available in respect of life-fecundity tables, field life-tables and key mortality factors of this pest in India.

Life-tables and key mortality factors are one of the tools most useful in the study of insect population dynamics. Field life-tables and key mortality factors may be analysed to determine what stage in the life cycle contributes the most to the population trend when series of life tables are available (Deevey, 1947; Harcourt, 1963, 1969; Atwal and Bains, 1974). The use of field life-tables have been made recently for studying the natural population of insect pests. When the environmental parameters are related to several causes of mortality, the field life-tables form a budget of the successive process that operate in a given population. Field life-table studies indicate which age interval and independent variable should be studied in detail for the effective control of the pest. It is also important to grasp the real situation of seasonal prevalence of an insect pest for planning its successful control (Harcourt, 1966, 1969; Morris and Millar, 1954; Singh et al., 1977).

A laboratory study on life-fecundity tables of a pest illustrates the relationship of development and survival of the life stages under ideal laboratory conditions. Because of the importance of reproductive ability or biotic potential, a statistics was developed to quantitatively explain population increase. This statistics is the innate capacity for increase, which is also called the true inherent or intrinsic rate of natural increase (Birch, 1948; Howe, 1953).

In the Pest Management Practices, the emphasis is always laid on bringing the population of the pest below economic threshold level. In the process it is equally essential to know the alternate hosts of the pests. So also the developmental period required on various hosts is equally essential from the point of view of forecasting as well.

Now-a-days with the irrigation facilities available in Marathwada region the cultivators having very light soil are opting for cultivation of pomegranate. As this being an alternate host of Achaea janata, the studies on biology are utmost essential.

Keeping in view the importance of population dynamics and rate of multiplication of A. janata, in field and under laboratory conditions, the present studies were undertaken with the following objectives.

1. To study the biology of A. janata on different hosts under laboratory conditions.
2. To study the biometrics of A. janata on important hosts.
3. To prepare life-fecundity tables of A. janata on castor, pomegranate, Euphorbia (Dudhi) and rose.
4. To study the life-tables and key mortality factors of A. janata during different generations on castor in field.
5. To prepare separate budgets with a aim to find out the key factors that influences the population trend of pest in castor.

II. REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Castor is rainfed crop and cultivated comparatively on small area as a sole crop. Some information is available on the aspect of chemical control of Achaea janata Linnaeus, however, less information is available on the aspects viz. field life-tables, biometrical studies and life-fecundity tables. After thorough screening of published literature, in respect of A. janata it was observed that, not much attention has been paid to study the above aspects on castor and other alternate host plants. In order to fall in line with the present studies, the literature reviewed includes the information on other insect species as well. The same is presented under the following headings.

- 2.1 The status of A. janata
- 2.2 Host range and extent of damage
- 2.3 Biology
- 2.4 Biometrics
- 2.5 Life-fecundity tables
- 2.6 Population dynamics and key mortality factors

2.1 The status of A. janata

Achaea janata Linnaeus belongs to the family Noctuidae of the order Lepidoptera. Almost all the species belonging to genus Achaea are major agricultural pests in the world. There are many species of Achaea

existing in nature. The larvae of Ophiusa melicerta Boisd (Achaea janata) occasionally occurred on tea plantation in Sumatra (Bernard, 1917). In Pretoria, South Africa, two species of Achaea viz., A. catella Guen and A. lienardi Boisd (Anonymous, 1921) have been observed. A. melicerta Boisd speci has been reported from Ceylon (Anonymous, 1918). Box (1941) from Sumatra reported four different species viz. A. leona Boisd, A. lienardi Boisd, A. mormoides Wlk, and A. satoculoides Hall. From Rhodesia five different species viz., A. albicilla Butt., A. vige-lascens Hamps, A. echo Wlk, A. sardida Wlk and A. trapezo-das Guen have been reported (Jack, 1923). Van (1946) reported the presence of A. janata L in Hawaii.

In India, Fletcher (1913, 1914) recorded the A. janata L. outbreak and its parasite in nature. He also observed the sudden outbreak of A. janata at Pusa in 1921. Occurrence of A. janata on castor at Delhi was recorded by Pruthi (1946).

Khan (1946) reported that A. janata occurs in middle of May on perennial crop of castor in Andhra Pradesh. He also observed four-five eggs per leaf and concluded that the activity of A. janata decreased from November onwards.

Massive out-break of the fruit piercing moth, A. lienardi Boisd and A. faber Hall occurred during the month of April in Ghana. About 90 per cent of mango

fruits were damaged by these moths and the larvae were observed to feed on forest canopy and wild plants (Anonymous, 1974).

A. janata appeared on castor from July to September in Karnataka State (Subramania, 1920). An outbreak of *A. janata* occurred on wild euphorbiaceous plants adjacent to cocoa and coconut plantation in Malaysia during May-June, 1982 (Ismail and Salim, 1982).

Pandey *et al.* (1967) reported that overwintered pupae of *A. janata* of earlier season gave rise to adults at the beginning of June in next season and the pest passed through five overlapping generations in a year.

A. janata remains active during September to November in Saurashtra of Gujarat State. The pest appeared in endemic form during middle of October and the attack was more severe in large compact blocks than in the small holdings and stray trees grown along the bunds and field boundaries (Tahiliani, 1985).

2.2 Damage and host range

2.2.1 Damage by larvae

The castor semilooper, *A. janata* is widely distributed throughout India. The larvae ate the leaves leaving only the ribs on old plant and the main stalk

on young plants. The top shoots and tender ~~leaves~~ ^{stems} were eaten on young plants (Subramania, 1920).

In South Africa, extensive injury to foliage of Exosaria reticulata L. was caused by the larvae of Achaea (Anonymous, 1923).

The first instar larva nibbled only the outer tissue of leaf. Second instar larvae damage the leaves and made holes, the third and fourth instar larvae completely defoliated the leaves. In the case of severe attack, whole field of castor was defoliated and sometimes even the stems were attacked and destroyed (Khan, 1946).

Srivastava and Pande (1966) reported that the injury made by first and second instar larvae was not so serious however, a combined attack of subsequent stage of leaves inflicted a heavy loss to the potential growth of the plants by devouring the leaves.

In Haryana, castor semilooper occurred in rainy season. The larvae ate the foliage and sometimes caused more damage by destroying the entire plant (Rahilla et al., 1980).

Tahiliani (1985) reported from Gujarat that there were on an average 24 leaves per plant on castor and all these leaves were completely eaten away leaving behind only hard mid ribs. There was total loss of crop in number of patches.

2.2.2 Damage by moths

There was considerable damage to ripening fruits of citrus by fruit piercing moth at Gwalior (Rakshpal, 1945). Van Der (1926) stated that the fruit piercing moths suck the sap juice from the fruits, produced dry spongy spots in the flesh and decay frequently followed by the injury in South Africa.

There was a massive out-break of fruit piercing moth, *A. lienardi* and *A. faber* occurred throughout the country in Ghana, Africa. About 90 per cent of mango fruits were damaged by the moths (Anonymous, 1974).

During the investigation on fruit piercing moth in Sierra Leone, 77 per cent of the moths caught belonged to species of *Achaea*, out of that 64 per cent of total number were caught on mango and only 1.5 per cent on citrus (Anonymous, 1945). Fruit moth, mainly *A. satella* destroyed as such as half of the apple crop in South Africa (Anonymous, 1921).

A. janata was observed to attack on fruits of guava, tomato, citrus in Nigeria. When the ripened fruits of mango, banana and grape were hanged in two orchards, it was observed that out of total 100 per cent moths were collected on mango, 28 per cent on banana and 12 per cent on grape fruits (Goldling, 1945).

Heavy fall of citrus fruits have been reported due to the attack of A. obvia; the moths which visit the trees at night and puncture the fruits before they are quite ripe. It was also estimated that 75 per cent of grape and orange fruits in Africa were destroyed by this pest (Patterson, 1917).

Pandey and Sukhani (1965) stated that the A. janata was serious pest of ripening fruits of C. limetta, C. paradisi and C. sinensis at Kanpur, India.

Pandey (1967) reported that the moths of A. janata were observed to puncture the ripening fruits of citrus, guava and caused rotting and premature fruit fall.

Castor semilooper, A. janata has been reported to cause damage to castor crop grown in many states of India (Narayanan, 1959). On the basis of literature reviewed, A. janata has been reported to feed 36 to 37 different host plants belonging to 20 families (Table 1). The family Leguminosae contributed maximum host plants (eight hosts) followed by Euphorbiaceae (four hosts).

It has been reported from Honolulu, Hawaii, that, A. janata larvae were reported to feed on Euphorbia bifida, E. hirta, leucaena glauca, Desmanthus virgatus, Acacia farnesia and Prosopis chilensis (Anonymous, 1946).

Golding (1945) reported from Nigeria, Africa, that, A. janata was observed to attack on the fruits of Jamun (Eugenia uniflora), guava (Psidium guajava), tomato (Lycopersicon esculentum), citrus (Citrus spp.), mango (Mangifera indica) and grape (Vitis vinifera).

A. janata was reported to feed on Pericopsis mooniana, Gymnogryllus hamerallis and Punica granatum in Cylone (Hutson, 1922, 1939).

Khan (1946) stated that A. janata feeds on rose (Rosa spp.), pomegranate (Punica granatum), Bauhinia sp., ber (Ziziphus jujuba), banian tree (Ficus bengalensis) and dudhi (Euphorbia tilufera) in Andhra Pradesh. The larvae of A. janata were recorded for the first time feeding on Phyllanthus niruri, Achyranthus aspera and Ficus religiosa (Pandey, 1967 and Pandey et al., 1967).

It was reported to feed on Bauhinia purpurea, Phaseolus mungo, Arachis hypogaea and Vigna mungo at Raichur in Karnataka (Jairamaiah et al., 1975; Panchbhavi and Holihosur, 1982 and Sangappa et al., 1981).

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). A. janata larvae were reported to feed on soybean leaves during kharif season at Parbhani (Mundhe, 1980).

In Maryana, A. janata was recorded as a minor pest of sunflower (Rahilla et al., 1980). The larvae of Ophiura melicerta (A. janata) occasionally occurred on tea plantation in Sumatra (Bernard, 1917). Van (1941) reported from Hawaii that larvae of A. janata were observed on Tournefortia-argentea.

2.3 Biology

2.3.1 Egg

Khan (1946) reported that, the eggs of A. janata hatched in 2-3 days. The egg period of castor ranged from 3-5 days (Pandey et al., 1967).

Pandey (1967) reported that, the eggs were laid usually on the lower surface of castor leaves and they were hatched after 2-4 days. The incubation period of egg of A. janata was 2-3 days (Grunwald, 1930).

The egg period of Achaea was 3 days on castor leaves in laboratory (Snee, 1962). Subramania (1920) reported that the egg period of A. janata was 2-4 days.

Srivastava and Pande (1966) reported that the egg period of Achaea varied from 2-4 days during monsoon and considerably increased in winter.

Incubation period on castor and pomegranate was 2.02 and 3.00 days, respectively (Byale and Bilapate, 1987).

2.3.2 Larva

2.3.2.1 Larval instars

Khan (1946) stated that there were four instars of A. janata on castor. Ramdev and Rao (1979) observed five larval instars of Achaea when reared on castor leaves.

Five larval instars were reported when larvae were reared on castor leaves (Srivastava and Pande, 1960). A. janata could complete five and six larval instars when reared on castor and pomegranate, respectively (Byale and Bilapate, 1987).

2.3.2.2 Larval period

The larval period of A. janata on castor ranged from 9 to 23 days. The larvae feed on lower epidermis of leaves in first instar, make holes in second instar and completely consumed the leaves during the last three instars. Cannibalism rarely occurred in the absence of food (Pandey et al., 1967).

Pant and Anand (1975) reported that, the larval period of A. janata lasted for 12 to 15 days when reared on artificial diet (5 per cent leaf powder) and 8 to 12 days on castor leaves.

The larval stage lasted for 13.55 days and maximum food intake (85 per cent of the total) was observed in fifth instar (Ramdev and Rao, 1979).

Subramania (1920) reported that the larval period of Achaea was lasted for 15 to 21 days after which the larvae descended to ground to pupate in dry leaves and weeds underneath the plants.

The larval period of Achaea lasted for 11 to 17 days on castor leaves under laboratory conditions (Smee, 1962). According to Khan (1946) it was 12 to 13 days on castor leaves.

Srivastava and Pande (1966) reported that, the total larval period of Achaea occupied from 10 to 16 days in monsoon and 15 to 31 days in winter season. Byale and Bilapate (1987) observed it 12.38 days when reared on castor.

2.3.3 Pupa

Ismail and Salim (1982) reported that, pupation of Achaea took place in loose cocoon in soil, between leaves spun together and pupal stage lasted for 10 days. According to Subramania (1920), the pupal stage lasted for 10 to 14 days. Smee (1962) observed 9 to 14 days pupal period on castor leaves.

The pupa of Achaea overwintered from November - December in the soil or in dry leaves and gave rise to adult at the beginning in June at Kanpur. The pupal period ranged from 7 to 26 days on castor (Pandey et al., 1967). Pupal period in dry weather was short,

whereas in the cold weather it was slightly longer and it ranged from 11 to 27 days (Khan, 1946).

According to Srivastava and Pande (1966), the pupal case breaks in V form and the moth emerges from the anterior region. The pupal period of Achaea varied from 10 to 15 days, the duration however, becomes more during cold season. They also observed the length and breadth of male and female pupae and it averaged 2.1, 0.63 and 2.3, 0.7 cm, respectively.

Khan (1946) stated that, the size of the 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 while in female pupa it varied from 2.0 to 2.5 and 0.7 to 0.8 cm, respectively.

The genital opening is a slit like and is situated on the 8th and 9th abdominal segments in female and male, respectively. The sex ratio was 57:43 (M:F). Pandey (1967) reported 11 to 18 days pupal period on castor.

Dani et al. (1980) prescribed the method to differentiate the male and female pupae of Achaea on the basis of distance between the genital and anal aperture and the distance is less in case of male and is more in case of female.

The average pupal period was 8.30 days on castor while in male and female it was 8.72 and 7.93 days respectively (Byale and Bilapate, 1987).

2.3.4 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 Ismail and Salim (1982), the life cycle was completed in 30 days on castor. It was 40 to 45 days in castor (Pandey, 1967).

On the basis of average leaf area consumption, weight of final instar larvae and pupae, pupal period and percentage of pupation, castor was the most suitable food plant followed by pomegranate, ber and guava (Singh, 1985).

The female had a shorter life cycle than the male (Byale and Bilapate, 1987). The life cycle of Achaea ranged from 29 to 35 days on castor in Gujarat during the active period of pest (September-November) (Tahiliani, 1985).

2.3.5 Adult

2.3.5.1 Pre-oviposition

The pre-oviposition period of A. janata was 6 to 21 days on castor (Khan, 1946). Smea (1962) observed that the pre-oviposition period was 4 to 10 days and adult lived for 10 to 20 days.

After copulation, female usually took 7 to 21 days as pre-oviposition period on castor. The adult longevity remained 9 to 10 days and 14 to 15 days for male and female respectively when adults were kept in pairs provided with guava fruits as a food (Srivastava and Pande, 1966).

The pre-oviposition period was 3 days when larvae were reared on castor leaves (Byale and Bilapate, 1987). Koshiya et al. (1986) reported 5 days pre-oviposition period of A. janata on castor.

2.3.5.2 Oviposition

Pandey et al. (1967) reported that the oviposition period of A. janata was 2 to 11 days on castor leaves. Srivastava and Pande (1966) reported that the oviposition period of A. janata varied from 2 to 7 days on castor.

The oviposition period of A. janata was 7 (Bilapate, 1987), 6 (Koshiya et al., 1986) and 5 days (Smee, 1962) on castor leaves.

2.3.5.3 Fecundity

Subramania (1920) stated that the eggs were deposited singly on the lower surface of the castor leaves at night and a female laid about 400 eggs.

Grunwald (1930) observed that the female of A. janata laid about 400 eggs on the lower surface of castor leaves.

Female cages singly and fed with a honey and water laid 600 eggs under laboratory conditions (Smees, 1962). Srivastava and Pande (1966) reported that A. janata laid 90 to 300 eggs/female.

Pandey (1967) stated that, about 90 to 300 eggs were laid per female on the lower surface of castor leaves. The female lived longer (13 to 15 days) than males (8 to 10 days). Pandey et al., (1967) found that the female of A. janata on an average laid 622 eggs on castor leaves.

Byale and Bilapate (1987) observed that, A. janata female laid 467 eggs during its life time on castor leaves under laboratory conditions. According to Kashiya et al. (1986), the mean fecundity was 577 days/female.

2.4 Biometrics

Byale and Bilapate (1987) studied the measurements of head capsule width in successive instars when A. janata larvae were reared on castor and pomegranate leaves. It was observed that when larvae were reared on castor leaves, the larvae passed through five larval instars measuring 0.390, 0.706, 1.162, 1.893 and 2.769 mm

head capsule width. They further observed that when larvae were reared on pomegranate leaves, the larvae passed through six instars and the mean head capsule width was 0.361, 0.595, 0.936, 1.462, 2.124 and 2.814 mm, respectively.

The larvae of *A. janata* were reared on seven different host plants in laboratory. On the basis of larval weight, castor was the most preferred food plant followed by rose, pomegranate, ber *Euphorbia hirta*, *Bauhinia* sp. and banian (Srivastava and Pandey, 1968).

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 instar width and grew in a geometrical progression.

Dyar (1890) studied the head capsule width of 23 species of Lepidopterous larvae and found that width was relatively static during a instar and grew in geometrical progression on successive stage of larva. The growth ratio remain constant to particular species. By using this ratio it was possible to determine the exact number of instars of an insect.

On the basis of average leaf area consumption, weight of final instar larvae and pupae, pupal period and per cent pupation, castor was the most suitable food plant followed by pomegranate, ber and guava (Singh, 1935).

2.5 Life-fecundity tables

The intrinsic rate of increase is a basic parameter which an ecologist may wish to establish for an insect population. Birch (1948) defined the intrinsic rate of increase as actual rate of increase of a population under specified constant environmental conditions in which space and food are unlimited when there are no mortality factors other than physiological ones. The life and fertility tables describes natality and its reaction with survival of insect population. He further suggested that the term intrinsic rate of natural increase might be considered more appropriate than an alternative term 'biotic potential', which is more frequently used in relation to insect population.

Pearl and Parker (1921) studied the life-table of Drasophila melanogaster Strains for the first time. According to Howe (1953), a life-table can be constructed by following the life history of a group of insects from their birth (egg laying) to emergence of adult and recording all deaths as they occur together with sex of these which die in as adult.

Scanty 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 Gujarat State. It was observed that the R_0 remained 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 number (λ) 1.20.

Similar studies on life-fecundity tables have been reported in the case of Dichocrocis punctiferalis Guenee (Bilapate, 1977), Traxoderma granarium Everts (Atwal et al., 1968), Heliothis armigera (Hubner) (Bilapate et al., 1980), Spodoptera litura Fabricious (Bilapate et al., 1980), Utethesia pulchella Lin. (Bilapate, 1984).

Life-table studies were also made in the case of parasites viz. Eriborus trochan teratus Morley (Chundurwar and Rao, 1975), Acathis unicolorate (Shenefelt) (Chundurwar, 1977), Trichogramma spp. (Orphanides and Gonzales, 1971).

2.6 Population dynamics

The damage to grape and orange fruits was reported to the extent of 75 per cent in Gold Coast, Africa (Patterson, 1917).

Subramania (1920) studied distribution of Achaea in Karnataka and according to him, the pest appeared in June-July and continued upto the end of September.

Braithwaite (1941) reported that the caterpillars of A. janata were most injurious during May-July in Burma. Rakshpal (1945) reported that considerable damage was caused by Achaea moths to ripened fruits of citrus during mid-night.

According to Lavabre (1954), Achaea was the most important leaf feeder on cocoa. The population generally increased considerably between July-August and December-January. Snee (1962) reported that Achaea caused extensive damage to young cocoa plants in New Guinea.

According to Jairamiah et al. (1975), the large number of leaves of Achaea were observed to feed on Bauhinia purpurea and other plants during August-September at Dharwad. Singh (1985) reported that, A. janata caused considerable damage to young plant of grafted ber and pomegranate in Rajasthan.

2.6.1 Natural enemies

Birds like mainly Acridotheres tristis (Linnaeus) fed on moths of Achaea to some extent. Moths were eaten by monkeys as well (Van Der Merwe, 1926).

Ramkrishna (1921) reported that Microplitis ophiussae Raman, braconid was one of the most important larval natural enemies including Telenomus proditor Nixon in Andhra Pradesh. The strips of parasitized eggs were attached to castor plants in fields and it was observed that the emerged parasite adults oviposited A. janata egg on infested plants under biological control project at Mahabubnagar. The releases were made in several neighbouring localities during 1973, 1974 and 1975 and the parasite recoveries from newly established population were to the extent of 61.47, 64.7 and 78.33 per cent, respectively (Thobbi et al., 1976).

According to Rao (1977), two predatory bugs viz. Cantheconidea furcellata Wolff and Rhinocoris fuscipes Fabr were observed to feed on late instar larvae of Achaea.

According to Rai and Jayaramaiah (1978), Microplitis maculipennis Sziepliget1 parasitized the larvae of A. janata to the extent of 70 to 75 per cent in field. According to them, some species of birds were effective predators on third and fourth instar larvae as well. The partial defoliation of castor plants and exposure on conspicuous size of larvae attracted the predators like house crow, Corvus splendens Viellot, maina, Acridotheres tristis (Linn) field crow, Corvus macrorhynchos, and sparrow, Spizella passerina and

House sparrow, Passer domesticus Linnaeus. Thobbi and Singh (1974) reported that the larvae of Heliothis armigera Hub. were found to prey on pupae of A. janata.

The birds like sparrow and common crow preyed upon the fifth instar larvae of Achaea however, the predation was not enough to keep the pest under check in Gujarat (Tahiliani, 1985). In all 21 parasites have been reported on A. janata in India (Table 2).

2.6.2 Field life-tables and key mortality factors

Though there is considerable information available on the control aspects of A. janata, relatively, less information is available on field life-tables and key mortality factors of castor semilooper in India. The literature reviewed includes the information on other insect species as well.

Singh et al. (1977) constructed the life-tables and budgets of Chilo partellus (Swinhoe) for monsoon. A positive trend index indicated that (1.15) the mortality factors operating during the pre-monsoon period were not effective in causing decline in borer population. The maximum contribution towards the generation mortality was of the first two larval instars and also owing to reduced fertility and egg viability.

Brar and Bains (1979) studied the population dynamics and mortality factors of Pyrilla perpusilla Walker in Punjab. The 'K' values worked out for each generation showed that different factors were important for different generations. Lethal effect of high temperature (above 43°C) on egg stage was the key factor in first generation.

According to Bilapate (1981), Camponotus chlorideus Uchida was important mortality parameter in all the five generations of Heliothis armigera (Hubner) on cotton followed by Goniophthalmus mali Mensil. There was decreasing trend in population and the pest passed through three generations in pigeonpea. The pest multiplied for three generations and C. chlorideus was the most important mortality parameter in chickpea. The larval parasite, Enicospilus biconatus Townes, was important mortality parameter of H. armigera on pigeonpea (Bilapate, 1981).

2.6.3 Generations

There were three generations of A. janata in Karnataka and the parasitization of larvae because of three species of braconid and tachinid was very high in second generation (Subramania, 1921). A. janata had five to six overlapping generations in Andhra Pradesh (Khan, 1946).

Table 1. Recorded host plants of Acnasa janata Linn in Indian literature

Family	Botanical name	Common name	State
Amranthaceae	<u>Achyranthes aspera</u> L.	--	Uttar Pradesh
Apocynaceae	<u>Carissa carandas</u> L.	Karunda	-do-
	<u>C. limetta</u>	Karunda	-do-
	<u>C. paradisi</u>	Karunda	-do-
	<u>C. sinensis</u>	Karunda	-do-
Combretaceae	<u>Quisqualis indica</u> L.	Barmasi	Rajasthan
Compositae	<u>Helianthus annuus</u> L.	Sunflower	Haryana
Euphorbiaceae	<u>Euphorbia</u> spp.	Dudhi	Uttar Pradesh
	<u>Phyllanthus niruri</u> L.	-	-do-
	<u>Ricinus communis</u> L.	Castor	-do-
Leguminosae	<u>Arachis hypogea</u> L.	Groundnut	Karnataka
	<u>Bauhinia purpurea</u> L.	Kanchan	-do-
	<u>B.</u> sp.	-	-do-
	<u>Glycine max</u> M.	Soybean	Maharashtra
	<u>Phaseolus mungo</u> L.	Mung	Karnataka
	<u>Vigna mungo</u> L.	Urd	-do-
Moraceae	<u>Ficus religiosa</u> L.	Peepal	Uttar Pradesh
	<u>F. bengaliensis</u> L.	Banlan	-do-
Musaceae	<u>Musa</u> spp. L.	Banana	--
Myrtaceae	<u>Psidium guajava</u> L.	Guava	Uttar Pradesh
Punicaceae	<u>Punica granatum</u> L.	Pomegranate	-do-
Rhamnaceae	<u>Ziziphus jujuba</u> L.	Ber	Andhra Pradesh
Rosaceae	<u>Rosa</u> spp. L.	Rose	Uttar Pradesh
Rutaceae	<u>Citrus</u> spp. L.	Citrus	-do-
Sapindaceae	<u>Dodonea viscosa</u> L.	Jakhmi	Rajasthan

Table 2. Parasites recorded on *A. janata* L.

Family	Scientific name	State/ country	Host stage
Braconidae	<u>Apanteles ruidus</u> Wlk.	Maharashtra	Egg
	<u>A. spp.</u>	Punjab, Orissa, Tamil Nadu	Egg
	<u>Bracon</u> sp.	Maharashtra	Larva
	<u>Microplitis maculipennis</u> Szep.	India/U.K.	Larva
	<u>M. ophiussae</u> Raman	Karnataka	Larva
	<u>Rogas percurrans</u> Lyle	India/ U.K.	Larva
Eulophidae	<u>Euplectus leucostomus</u> Roh.	India	Larva
Ichneumonidae	<u>Hemicospilus</u> sp.	India	Larva
	<u>Hymenobosmina</u> sp.	India	Larva
	<u>Paniscus ocellaris</u>	India	Larva
	<u>Microtoxidea lessanata</u> Vier.	India	Larva
	<u>Zaminochorus orientalis</u> Viet.	India	Larva
Scelionidae	<u>Telenomus Predator</u> Nixon	Andhra Pradesh	Egg
	<u>I. sp.</u>	Karnataka	Egg
	<u>I. remus</u> Nagraja	Karnataka	Egg
	<u>I. sp.</u>	India	Larva
Tachinidae	<u>Chotoxaedia menticola</u> Big	Hawaii	Pupa
	<u>Tricolyga sobillans</u> Wied.	India	Larva
Tetranychidae	<u>Tetrastichus ophiussae</u> Crawford	India	Larva
Trichogramma- tidae	<u>Trichogramma achaeae</u> Nagraja and Nagarkatti	Karnataka	Egg
	<u>T. armigera</u> Nagraja	Karnataka	Egg
	<u>Trichogrammatia bacterae</u> Nagraja	Karnataka	Egg
	<u>Trichogramma australicum</u> Gir.	China	Egg
	<u>T. dendrolium</u> Mats.	China	Egg
	<u>T. evanescens</u> Westw.	Andhra Pradesh	Egg
	<u>T. minutum</u> Ril	Andhra Pradesh	Egg
	<u>T. Prabakeri</u>	Karnataka	Egg
	<u>T. Sp.</u>	India	Egg
	<u>T. sp.</u>	Sumatra	Egg

A. janata passed through five to six generations in a year on castor (Pandey, 1967). Pandey et al. (1967) recorded five overlapping generations in a year on castor in Uttar Pradesh.

Srivastava and Pande (1966) recorded five generations in a year in Rajasthan. Hua (1981) stated that there were six to seven generations in a year with no apparent over wintering in China.

III. MATERIALS AND METHODS

III. MATERIALS AND METHODS

With a view to find out the suitability of the host, life-fecundity tables, key mortality factors and preparation of budgets, experiments were conducted at College of Agriculture, Parbhani. The materials used and methods adopted in various experiments are presented below.

- 3.1 Rearing of test insect
- 3.2 Biological studies
- 3.3 Biometrical studies
- 3.4 Life-fecundity tables on different hosts under laboratory
- 3.5 Field life-tables, key mortality factors in field on castor and preparation of budget.
- 3.6 Statistical analysis

3.1 Rearing of test insect

The initial culture of castor semilooper, *A. janata* was started by collecting a large number of larvae during July, 1985 and 1986 from stray castor plants in fields. The larvae were reared individually in 5 x 5 cm round plastic boxes and tender castor leaves were provided as food. The boxes were cleaned and fresh food was provided to larvae every day in the morning until pupation. The larvae formed a silken cocoon during pre-pupal stage. After pupation the sexes of pupae were determined on the basis of distance between the two



aperture. In the case of male, the distance between genital aperture and anal aperture is less while it is more in case of female (Dani et al., 1980; Srivastava and Pande, 1966).

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In adult male, the margins of fore wings are usually prominent. The dirty white patches between anti-and post medial vein are quite distinct. In female, these markings and lines are almost absent due to dark-brown coloured scales. The freshly emerged male and female moths (1:1) were released in oviposition cage made up of iron wire guage (25 x 60 cm) with one muslin cloth slit on top of the cage. Cotton wool swabs dipped in ten per cent honey solution were suspended with the help of 'U' pins from the top in a hanging position. These cotton swabs were replaced daily. The tender castor twigs with succulent leaves were kept in small conical flask containing water and placed into the cage as an oviposition substrate. Soon after egg laying, known number of eggs were placed in petridish (10 cm diameter). The newly hatched larvae were carefully removed with the help of wet camel hair brush and released on fresh food of castor, Ricinus communis L., pomegranate, Punica granatum L., dudhi, Euforbia sp. L., and rose, Rosa spp. All the larvae were reared individually on different alternate hosts. Foods were changed daily in morning till the larvae pupated. The rearing was conducted through two

consecutive generations on respective hosts, for acclimatization and in third generation, the culture was used for all laboratory investigations. During the course of investigations, the prevailing average laboratory minimum and maximum temperatures were 25°C to 30°C, respectively.

The details of the experimental procedure given below pertains to the larvae reared on castor, pomegranate, Euphorbia and rose.

3.2 Biological studies

With a view to study the biology of the pest the four separate experiments were conducted by using four different alternate hosts viz, castor, pomegranate, dudhi and rose. In each of the experiments the eggs obtained from the respective food material were kept in petri-dishes for hatching.

The newly hatched larvae (100) were reared individually in five replications containing 20 larvae in each of the replicate. In all 400 larvae were used for these experiments.

The observations were recorded on the larval duration, per cent larvae pupated and growth index in respective hosts. After pupation, all the pupae were sexed. The pupal weight was recorded on 4th day after pupation. Observations were also made on pupal length, pupal width, pupal duration in both the sexes.

The adults emerging from respective host plants on the same day (male:female) were paired and released for egg laying in oviposition cages. Ten per cent honey solution was provided daily for adult feeding. The fresh twig of respective host plants were kept in the oviposition cage as substrate for egg laying and observation on pre-oviposition and oviposition periods were noted. The number of eggs laid by the female were counted daily till the female died.

3.3 Biometrical studies

The neonate larvae (100) immediately after hatching on respective host were transferred in separate plastic boxes (5 x 5 cm) and were reared individually on castor, pomegranate, dudhi and rose leaves. In all 400 larvae were used for four hosts. Fresh food was supplied everyday and observations were recorded under microscope on the casting of exuvae. Immediately after each moult, the head capsule of each instar was collected and width of the same was measured using microscope by placing ocular micrometer in the eye piece. The instar duration of A. janata was studied when larvae reared on castor, pomegranate, Euphorbia and rose leaves. The application of Dyar's rule (1890) was tested for the number of larval instars when reared on different hosts. For the purpose of assigning single individuals to their respective instars regression relationships between instar and the mean head capsule width of larvae was calculated.

The regression relationship between the instar and mean head capsule width in different instars was calculated using following equation.

$$\log_{10} Y = a + b_x$$

where,

- y = head capsule width of larvae
- a = constant
- b = logarithm of growth ratio
- x = number of instars

3.4 Life-fecundity tables

In order to construct the life-fecundity tables on castor, pomegranate, dudhi and rose, 100 eggs were placed in 5 replicates consisting 20 each. In all 400 eggs were utilized for this studies. Soon after hatching, all the larvae were reared incividually on respective hosts. Fresh food in the form of tender leaves was provided daily. Observations on hatching, larval and pupal development, successful adult emergence, fecundity and age specific mortality in eggs, larvae, pupae and adults were recorded daily. For determining the age-specific fecundity, the total number of adults emerged on a particular day were transferred to a separate cage for egg laying. A fresh healthy twig of respective host plant was kept in the breeding cage as oviposition site. The cotton swab soaked in 10 per cent honey solution was provided daily as a

adult food. Considering the sex ratio (1:1) (Southwood, 1968), the number of eggs laid per female were divided by two to get the number of female births (m_x).

The column headings proposed by Birch (1948), elaborated by Howe (1953) and Atwal and Bains (1974) were used for the construction of life-fecundity tables under laboratory conditions.

- x = pivotal age in days
- l_x = survival of females at age 'x'
- m_x = age schedule for female birth at age 'x'

3.4.1 Net reproductive rate

The value of 'x', ' l_x ' and ' m_x ' were calculated from the data on life-tables. The sum of products ' $l_x m_x$ ' is the net reproductive rate (R_0) (Lotka, 1925). ' R_0 ' 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 formula:

$$R_0 = \sum l_x m_x$$

3.4.2 Mean generation time

The approximate value of a cohort generation value time (T_c) (the mean age of the mothers in a cohort at the birth of female offspring) was calculated as follows:

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

3.4.3 Innate capacity for increase in numbers

The numbers of individuals survived as well as the mean number of female offsprings produced at each age interval was recorded. From the data in life-table, the arbitrary value of ' r_m (r_c)' was calculated by using the formula (Laughlin, 1965).

$$r_c = \frac{\log_e R_0}{T_c}$$

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 the second decimal place by interpolation with the formula (Birch, 1948 and Watson, 1964).

$$\sum e^{7-r_m x} l_{xm} = 1096.6$$

Tables were then constructed for each host plant with columns ' x ' and ' l_{xm} ' for each trial ' r_m '. The two trial values of $\sum e^{7-r_m x} l_{xm}$ were then plotted on the horizontal axis against their respective arbitrary ' r_m 's on the vertical axis. The points were joined to give a line which intersected a vertical line drawn from the desired values of $\sum e^{7-r_m x} l_{xm} = 1096.6$. The point of the intersection gave the value of true ' r_m ' accurate to four decimal places. The precise generation time (T) was then calculated from the formula,

$$T = \frac{\log_e R_0}{r_m}$$

3.4.4 The finite rate of natural increase (λ)

The finite rate of natural increase (λ) i.e. female/female/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,

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

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

3.5 Field life-tables and key mortality factors

3.5.1 Field generation studies

A non-replicated trial was conducted in two tires comprising of total 100 quadrates of 2.4 x 2.1 m size. During the present investigation, a castor variety, VI-9 was raised for studying the number of generations of *A. janata* and its parasite in the field. During the kharif season, the castor crop was sown on main farm, College of Agriculture, Parbhani for two consecutive years, 1985-86 and 1986-87. Frequent field visits were made in order to record the first incidence of (egg stage) of *A. janata* on castor crop. All the tests were conducted under pesticide free conditions.

The known number of eggs (as a start of incidence) were collected carefully and separated alongwith plant materials adhering to them. These eggs were brought to laboratory and after hatching, these tiny larvae were reared in circular plastic boxes (5 x 5 cm) individually on castor leaves till pupation. The same culture of *A. janata* was consistently reared on castor leaves in the laboratory untill the complete ceass^eion of pest population in the field. This culture was used as a check for further studies.

Since there are over-lapping generations of the pest where all stages of the pest are found simultaneously, the sampling for the regular generation in the field was based on the developmental stages of pest reared in check culture in laboratory. This generation was considered to be a distinct from the overlapping generations for the pest in field conditions.

When the larvae in check culture in the plastic boxes reached I to III instars (early instars) sampling (2 x 2 cm quadrates) for the larvae was made in the field, similarly, when the larvae passed through IV and V instars, (late instars) under laboratory conditions, sampling for the respective instar was made in the field. Known number of sample quadrates were observed in early and late instar group. The plants in the sampled quadrates were carefully observed for the presence of larvae and such five quadrates were observed in each standard meteorological week.

The total observed larvae from respective quadrates were carefully collected and brought to laboratory for further studies. These collected larvae were reared on castor leaves until pupation. The observations were recorded regarding the mortality of larvae and pupae because of different parasites and unknown reasons.

An interval of six days was provided before sampling of larvae for next generation after the mean adult emergence of previous generation of the laboratory culture. This period was considered for completion of pre-oviposition act by the moths of previous generation. The meteorological details were recorded during the period of investigations. Known number of eggs of *A. janata* were collected from field during each generation and the mortality owing to sterility and the parasite if any was worked out.

3.5.2 Preparation of field life-tables

The column headings used in the present study were those proposed by Morris and Millar (1954) and Harcourt (1969).

x = the age interval, egg, larva, pupa and adult

l_x = the number surviving at the beginning of stage noted in the 'x' column

d_x = the number dying within the age interval stated in the 'x' column

d_x^F = the mortality factor responsible for ' d_x '

$100 q_x$ = percentage mortality

S_x = survival rate within the age mentioned in the 'x' column.

3.5.3 Criteria for filling the columns of field life-tables

Harcourt (1963) proposed the criteria for filling the data in the life-table for each age interval (stage). The same criteria was used in the present investigation.

3.5.3.1 Egg

The viability of eggs was determined on the basis of field collected eggs and thus the ' d_x ' value was worked out. The ' l_x ' for eggs was derived indirectly on the basis of sterility of viability of eggs.

3.5.3.2 Younger larvae (I to III instar)

The ' l_x ' for I to III instar larvae was obtained by direct sampling of the quadrates and computed on hectare basis.

3.5.3.3 Older larvae (IV to V instar)

The ' l_x ' was obtained by deducting the mortality due to parasites and unknown causes from the younger larvae (I to III instar).

3.5.3.4 Pupae

The ' l_x ' was determined after subtracting the mortality owing to parasite and unknown causes from the population of (l_x) older larvae.

3.5.3.5 Moths

This ' l_x ' represents the number of pupae giving rise to adults. The mortality in the pupal stage due to parasites and unknown causes was subtracted from ' l_x ' of pupae and thus the ' l_x ' value for moths was determined. The sex ratio was 1:1 or 50 per cent females. 'Female x 2' was simply the percentage of females applied to ' l_x ' for moths.

3.5.4 Trend index (I)

This was simply ' l_x ' for younger larvae in the preceeding generation expressed as a ratio of the succeeding one.

$$\text{Trend index} = \frac{N_2}{N_1}$$

whereas,

N_2 = population of early instar larvae in next generation

N_1 = population of early instar larvae in previous generation.

3.5.5 Generation survival (SG)

This was an index of population trend without the effect of fecundity and adult mortality.

$$\text{Generation survival} = \frac{N_3}{N_1}$$

Whereas,

N_3 = population of adults (female) in a generation

N_1 = population of early instar larvae in the same generation.

3.5.6 Analysis of causes of fluctuations of population and identification of key mortality factors

The most important step in explaining the population fluctuations is to determine the stage in the life of the pest which has major contribution to the index of population, trend (1) of generation survival (SG). Separate budget for each generation was prepared to find out the key factors that influenced the population trend in different generation. The method of key factors analysis developed by Varley and Gradwell (1963 and 1965) was used to detect density relationship of mortality factors. By this method, the killing power (k) of such mortality factors in each age group was estimated as the differences between the logarithms of population density before and after its action. As a series of mortality factor operated in succession during a generation on a population, the total killing power of 'k' was equal to the sum of the killing powers of k's.

If $k_1 = \log l_x$ of egg stage - $\log l_x$ of larval stage, $k_2 = \log l_x$ of larval stage - $\log l_x$ of pupal stage, and $k_3 = \log l_x$ of pupal stage - $\log l_x$ of adult stage. Thus, K will be equal to $k_1 + k_2 + k_3$.

3.6 Statistical analysis

The data obtained pertaining to biological and

biometrical studies under this investigations were statistically analysed by Randomised Block Design 'Analysis of Variance' method (Panse and Sukhatme, 1967). Means obtained were subjected to Dunkan's Multiple Range Test for comparison between the two means.

IV. EXPERIMENTAL FINDINGS

IV. EXPERIMENTAL FINDINGS

The findings obtained in the present investigations on the different aspects of castor semilooper, Achaea janata Linnaeus are being reported under the following heads:

- 4.1 Biology of A. janata on different hosts under laboratory conditions
- 4.2 Biometrical studies of A. janata on important hosts
- 4.3 Preparation of life-fecundity tables of A. janata on castor, pomegranate, Euphorbia sp. and rose
- 4.4 Field life-tables, key mortality factors and preparation of budget.

4.1 Biology on different hosts

The biology of A. janata was studied on castor, pomegranate, dudhi and rose under laboratory conditions. The results in Table 13, 14 and 15 suggest that the food plants significantly affected the growth, survival and reproduction of A. janata on different hosts.

Table 3 shows that the mean percentage pupation ranged from 55 on rose to 94 per cent on castor. Castor and dudhi recorded significantly higher per cent pupation than rose and pomegranate. While the per cent pupation on pomegranate and rose was relatively low, the difference between these host plants were not significant. The mean larval duration was shortest on

castor (11.71 days) and longest (24.77 days) on pomegranate. There were no significant differences in the larval duration between pomegranate and rose. The growth index value was highest for castor (8.02) followed by dudhi (4.36), while the lowest growth index value (2.26) was obtained in pomegranate and rose. The pre-pupal period was shortest on dudhi (2.0 days). The highest mean per cent (94) adult emergence was recorded on castor followed by dudhi (76). However, pomegranate and rose were at par in respect of mean adult emergence.

Significant differences were observed in pupal duration. It was shortest on castor (8.93 days) and longest on pomegranate (10.32 days). There were no significant differences in pupal durations on pomegranate and dudhi. In general, females emerged earlier than the males on all the host plants tested except rose. The pupal duration for male was shortest (9.24 days) on castor and longest on rose (11.56 days). There were no significant differences in the pupal durations between pomegranate and dudhi. The shortest (8.67 days) pupal duration for female was recorded on castor and longest (12.70 days) on rose. There were no significant differences in the pupal durations of females when reared on castor, pomegranate and dudhi.

Table 3. Mean per cent pupation, larval duration, growth index and pupal duration of *A. janata* on different hosts

Host	Mean per cent larvae pupated (n)	Mean larval duration (days)	Growth index (n/mean)	Pre-pupal duration mean (days)	Mean per cent adult emerged	Mean pupal duration (days)	
						General	Male Female
Castor	94 a	11.71 b	8.02	2.01 a b	94 a	8.93 c	9.24 c 8.67 b
Pomegranate	56 c	24.77 a	2.26	2.01 b	54 c	10.32 b	10.46 b 10.08 b
Dudhi	80 b	18.32 c	4.36	2.00 b	76 b	9.72 b c	10.25 b 9.51 b
Rose	55 c	24.51 a	2.26	2.07 a	51 c	10.28 a	11.56 a 12.70 a
S.E. ±	4.38	0.50	-	0.01	6.41	0.26	0.31 0.31

Means in the same column followed by the same letter are not significantly different (P = 0.05) by Duncan's Multiple Range Test.

The results on pupal length, width and weight are summarised in Table 4.

The mean pupal length was more on castor (21.49 mm). There were no significant differences in the mean pupal length of larvae reared on different hosts. The male pupae measured 21.78 mm on castor and 21.38 mm on dudhi, respectively. There were no significant differences in length of male pupae in all the host plants tested. There were no significant differences in the pupal length of females as well.

The average pupal width ranged from 6.17 to 7.18 mm on rose and castor and there were no significant differences between pomegranate and dudhi. The differences in the pupal width of male pupae remained at par when larvae reared on castor, pomegranate and dudhi. There were no significant differences in the length of female pupae when reared on all the host plants tested.

The highest mean pupal weight (670 mg) was recorded on castor and lowest (470 mg) on rose. The mean pupal weight of male pupae was highest (710 mg) on castor and lowest (470 mg) on rose. There were no significant differences in the pupal weight of male pupa on pomegranate and dudhi. In female, mean pupal weight was highest i.e. 670 mg on castor and it was significantly superior over rest of the host plants tested.

Table 4. Mean pupal length, width and weight of *A. janata* on different hosts

Host	Mean pupal length (mm)			Mean pupal width (mm)			Mean pupal weight (mg)		
	General	Male	Female	General	Male	Female	General	Male	Female
Castor	21.49 a	21.78 a	21.64 a	7.18 a	7.22 a	7.26 a	670 a	710 a	670 a
Pomegranate	20.28 a	20.23 a	20.28 a	6.73 b	6.84 a	6.81 a	580 b	600 b	500 b
Dudhi	20.72 a	21.38 a	20.33 a	6.90 a b	7.10 a	6.82 a	560 b	570 b	550 b
Rose	20.00 a	20.03 a	20.01 a	6.17 c	6.06 b	6.25 a	470 c	470 c	480 b
S.E. $\pm$	0.47	0.16	0.45	0.11	0.15	0.13	0.01	0.01	0.02

Means in the same column followed by the same letter are not significantly different ($P = 0.05$) by Duncan's Multiple Range Test.

Table 5 indicates that mean pre-oviposition period ranged from 5 to 7 days when larvae were reared on different hosts. The longest (8.02 days) oviposition period was observed on castor and shortest (6.63 days) on rose. However, the mean oviposition period did not differ significantly for all the host plants tested. The highest number of eggs (636.0) were laid by the moths obtained from larvae reared on castor followed by pomegranate (541.6), roses (389.4) and dudhi (336.6). The moths obtained from rose and dudhi remained at par in respect of fecundity. The incubation period was 2.00 days irrespective of host plants tested.

The mean total life cycle was shortest (24.43 days) on castor followed by dudhi (32.09 days) and it was longest (40.33 days) on rose. In respect of mean life cycle, castor was significantly superior over rest of the host plants tested. In general, the males had longer life cycle than the females.

Table 5. Mean pre-oviposition, oviposition, fecundity and life cycle of *A. janata* on different hosts

Host	Mean pre-oviposition period (days)	Mean oviposition period (days)	Fecundity	Mean life cycle (days)		
				General	Male	Female
Castor	6	8.02 a	636.0 a	24.48 c	25.09 c	24.45 c
Pomegranate	5	7.12 a	541.6 b	39.33 a	40.16 a	38.25 a
Dudh1	7	7.19 a	385.6 c	32.09 b	32.32 b	31.37 b
Rose	5	6.68 a	389.4 c	40.38 a	40.04 a	40.46 a
S.E. ±		1.50	13.18	0.63	0.75	0.88

Means in the same column followed by the same letter are not significantly different ($P = 0.05$) by Duncan's Multiple Range Test.

4.2 Biometrical observations

The head capsule width of *A. janata* was measured when larvae were reared on different hosts. The durations of instars were studied on different host as well. The results are being reported under the following heads.

4.2.1 Head capsule width on castor

The head capsule width of *A. janata* was studied during different instars on castor. The data obtained on mean observed and calculated head width of successive instars are presented in Table 6 and Fig. 1.

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

Details	Instars					Progre- ssion factor
	I	II	III	IV	V	
Observed head width (mm)	0.404 ± 0.046	0.671 ± 0.035	1.243 ± 0.156	2.085 ± 0.135	3.639 ± 0.119	
Growth ratio	-	1.660	1.852	1.677	1.745	1.73
Calculated head width (mm)	0.399	0.694	1.206	2.097	3.646	1.74
Difference	0.005	-0.023	0.037	-0.012	-0.007	
% differ- ence	1.253	-3.314	3.067	-0.572	-0.191	

It is evident from the Table 6 and Fig. 1 that the larvae when reared on castor leaves passed through five larval instars. The mean observed and calculated progression factors for head capsule width were 1.73 and 1.74, respectively. The equation for the straight line best fitting the observed head capsule width was,

$$\log_{10} Y = -0.2297 + 1.7383_x$$

4.2.2 Head capsule width on pomegranate

The data obtained on mean observed and calculated head capsule width for successive instars on pomegranate are presented in Table 7 and Fig. 1.

Table 7. Comparison of observed and calculated values (mm) of mean measurements for larval head capsule width of *A. janata* on pomegranate leaves

Details	Instars					Progression factor
	I	II	III	IV	V	
Observed head width(mm)	0.379 ±0.033	0.660 ±0.050	0.986 ±0.111	1.942 ±0.090	3.523 ±0.087	
Growth ratio	-	1.741	1.493	1.969	1.814	1.75
Calculated head width(mm)	0.366	0.638	1.110	1.931	3.361	1.74
Difference	0.013	0.022	-0.124	0.011	0.162	
% difference	3.551	3.448	-11.171	0.569	4.819	

data presented in Table 7 indicate that the larvae of *A. janata* when reared on pomegranate passed through five instars. The mean progression factors for observed and calculated head capsule widths were 1.75 and 1.74, respectively.

The equations for the straight line best fitting the observed head capsule width was,

$$\log_{10} Y = -0.2107 + 1.7399_x$$

4.2.3 Head capsule width on *Euphorbia* sp.

The data obtained on mean observed and calculated head capsule width on successive instars are given in Table 8 and Fig. 1.

Table 8. Comparison of observed and calculated values (mm) of mean measurements for larval head capsule width of *A. janata* on *Euphorbia* sp.

Details	Instars					Progression factor
	I	II	III	IV	V	
Observed head width(mm)	0.334 ±0.041	0.686 ±0.038	1.171 ±0.115	1.664 ±0.086	3.563 ±0.086	
Growth ratio	-	2.053	1.706	1.421	2.141	1.83
Calculated head width (mm)	0.356	0.625	1.097	1.924	3.376	1.75
Difference	-0.022	0.061	0.074	-0.260	0.187	
% difference	-6.179	9.760	6.745	-13.513	5.539	

It is clear from Table 8 that the larvae of *A. janata* when reared on dudhi leaves passed through five instars. The mean progression factor for observed and calculated value were 1.83 and 1.75, respectively.

The equation for the straight line best fitting the observed head capsule width was,

$$\log_{10} Y = -0.2037 + 1.7542_x$$

4.2.4 Head capsule width on rose

The data obtained on mean observed and calculated head capsule width of successive instars are presented in Table 9 and Fig. 1.

Table 9. Comparison of observed and calculated values (mm) of mean measurements for larval head capsule width of *A. janata* on rose

Details	Instars					Progression factor
	I	II	III	IV	V	
Observed head width (mm)	0.275 ±0.050	0.581 ±0.052	0.928 ±0.057	1.875 ±0.093	3.462 ±0.065	
Growth ratio	-	2.112	1.597	2.020	1.846	1.89
Calculated head width (mm)	0.285	0.531	0.992	1.851	3.454	1.86
Difference	-0.010	0.030	-0.064	0.024	0.008	
% difference	-3.508	5.649	-6.451	1.296	0.231	

It is evident from Table 9 and Fig. 1 that the larvae of A. janata when reared on rose leaves passed through five larval instars. The mean progression factors for observed and calculated head capsule width were 1.89 and 1.86, respectively in all the five instars. The equation for the straight line best fitting the observed head capsule width was,

$$\log_{10} Y = -0.1527 + 1.8658 x$$

The durations of different larval instars were studied when A. janata reared on castor, pomegranate, dudhi and rose. The results obtained are presented in Table 10. The durations of first instar larvae were 2.32, 2.77, 1.91 and 3.48 days on castor, pomegranate, dudhi and rose, respectively. Significant differences were observed in the duration of first instar larvae when reared on different hosts. The durations of second instar larvae ranged from 2.43 (castor) to 4.30 (rose) days. There were no significant differences in the duration of second instar larvae when reared on castor and rose as well as on pomegranate and dudhi. The shortest duration for third instar larvae was observed on castor (2.93) days, while it was longest on rose (4.69) days. The durations of fourth instar larvae were 2.98, 5.54, 3.47 and 5.06 days, respectively and they were significantly different from each other. The larvae took 4.97, 5.92, 7.45 and 7.18 days to complete fifth instar when reared on castor,

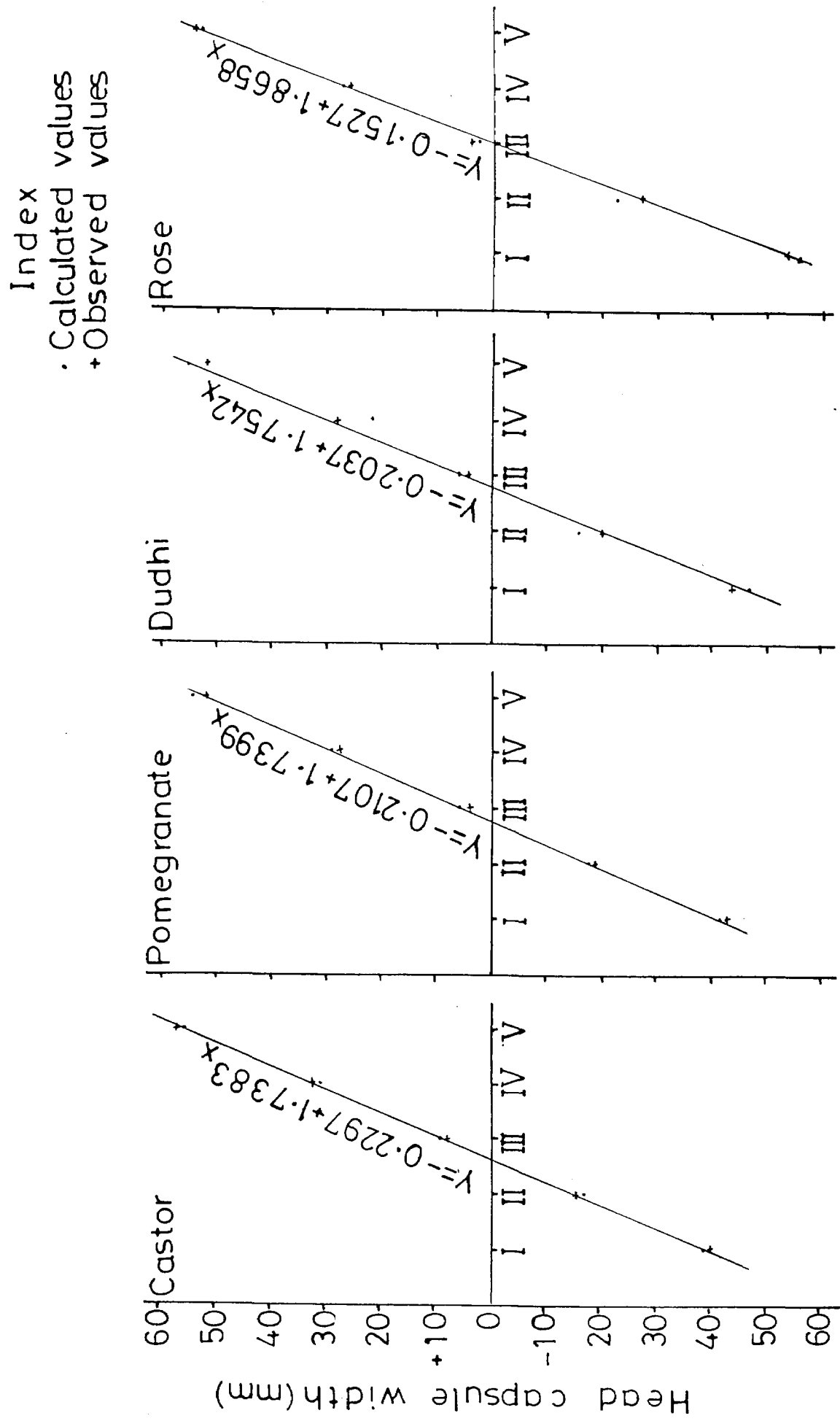


Fig 1 . Regression graph of instars (V) on mean head capsule width of A. janata on different hosts

pomegranate, dudhi and rose, respectively. There were no significant differences in the instar duration when larvae were reared on dudhi and rose.

Table 10. Duration of instars of *A. janata* on different hosts

Host	Instars				
	I	II	III	IV	V
Castor	2.32 c	2.43 a	2.93 c	2.98 d	4.97 c
Pomegranate	2.77 b	2.90 b	4.24 a b	5.54 a	5.92 b
<u>Dudhi</u>	1.91 d	3.10 b	3.84 b	3.47 c	7.45 a
Rose	3.48 a	4.30 a	4.69 a	5.06 b	7.18 a
S.E. $\pm$	0.0852	0.1846	0.2180	0.1477	0.1293

Mean in the same column followed by the same letter are not significantly different ($P = 0.05$) by Duncan's Multiple Range Test.

4.3 Life-fecundity tables

The life-fecundity tables of *A. janata* were constructed on four host plants viz. castor, pomegranate, dudhi and rose leaves. The observations were recorded on the hatching of egg, larval and pupal mortality in respective pivotal age, fecundity and age-specific mortality of females were also studied.

4.3.1 Castor

The data regarding the life-tables and age-specific fecundity of *A. janata* when reared on castor are presented in Table 11 to 15. The results of Table 11 indicates that the survival of *A. janata* was 100, 94 and 94 in respect of egg, larva and pupa in a cohort of 100 eggs. During the rearing of life stages, there was successful emergence of 44 males and 50 females.

Table 11. Survival of different life stages of *A. janata* during development of castor

Sr. No.	No. of eggs kept	Number surviving			Sex	
		Egg period 0 - 2 days	Larval period 3 - 17 days	Pupal period 18 - 29 days	Male	Female
1.	20	20	19	19	10	9
2.	20	20	20	20	7	13
3.	20	20	20	20	8	12
4.	20	20	18	18	9	9
5.	20	20	17	17	10	7
Total 100		100	94	94	44	50

It is apparent from the Table 12 and Fig. 2 that, the survival of immature stages (l_x) was 0.94 (based on one individual) per individual within a pivotal age of

29 days. The pre-oviposition period ranged from 30th to 35th day of pivotal age. The number of eggs laid per female were divided by two to get the number of female births (m_x). The female births were highest (53.05) on third day of oviposition at 38th day of pivotal age and decreased gradually thereafter. The first female mortality was observed on 5th day ($l_x = 0.92$) after initiation of oviposition when the culture was in the 40th day of pivotal age. The mortality rate of females slowly declined thereafter. The females oviposited for 9 days. The net reproductive rate (R_0) representing the total females per female was 325.94 females per female per generation. Thus, the population of *A. janata* would be able to multiply 325.94 times per generation on castor.

Table 13 indicates the results on mean generation length, intrinsic rate of increase in number and finite rate of increase in numbers of *A. janata*. The approximate generation time (T_c) was found to be 39.27 days. The arbitrary value for intrinsic rate of natural increase (r_c) was 0.1474 females per female per day. The precise generation time (T) was 38.83 days while the finite rate of increase in numbers (λ) was 1.16 females per female per day. The corrected innate capacity for increaseⁱⁿ numbers (r_m) was calculated and presented in Table 14 and Fig. 3.

Table 12. Life-fecundity table of *A. janata* on castor

Pivotal age in (days)	Survival of female at different age interval	Age sche- dule for female births		
x	l_x	m_x	$l_x m_x$	$l_x m_x X$
0-29	0.94	—	—	Immature stages
30-35	0.94	—	—	Pre-oviposition period
36	0.94	32.06	30.13	1084.91
37	0.94	49.41	46.44	1718.47
38	0.94	58.05	54.56	2073.54
39	0.94	57.58	54.12	2110.88
40	0.92	56.45	51.93	2077.36
41	0.90	35.77	32.19	1319.91
42	0.88	32.36	28.47	1196.02
43	0.81	22.77	18.44	793.07
44	0.67	14.42	9.66	425.10
45	0.47	0.00	0.00	0.00

$$R_0 = \sum l_x m_x = \sum l_x m_x X$$

$$= 325.94 = 12799.26$$

Table 13. Mean length of generation, innate capacity for increase in numbers and finite rate of increase in numbers of *A. janata* on castor

Population growth statistics

Mean length of generation

$$T_c = \frac{\sum l_m x}{R_0} \quad 39.27 \text{ days}$$

Innate capacity for increase in numbers

$$r_c = \frac{\log_e R_0}{T_c} \quad 0.1474 \text{ female/female/day}$$

Arbitrary r_m 0.13 and 0.15,

$$\text{corrected } r_m \leq e^{7-r_m} x_1 x_m = 1096.6 \quad 0.1490 \text{ female/female/day}$$

(Arbitrary value changing at second decimal place, each one from lower and higher position).

Corrected generation time.

$$T = \frac{\log_e R_0}{r_m} \quad 38.83 \text{ days}$$

Finite rate of increase in numbers

$$\lambda = \text{anti log}_e r_m \quad 1.16 \text{ female/female/day}$$

The two trial values of 2250.55 and 1038.37 were plotted on horizontal axis against their respective arbitrary r_c differing in second decimal place on either side of it i.e. 0.13 and 0.15 on vertical axis and corrected r_m was calculated by interpolation method. Thus, the corrected r_m was calculated as 0.1490 female per female per day.

Table 14. Calculation of r_m of *A. janata* by trial and error method on castor

Pivotal age (days)	$l_{x,m}$	$r_m = 0.13$		$r_m = 0.15$	
		$e^{7-r_m x}$	$e^{7-r_m x} l_{x,m}$	$e^{7-r_m x}$	$e^{7-r_m x} l_{x,m}$
30-35	—	—	—	Pre-oviposition period	
36	30.13	10.18	306.72	4.95	149.23
37	46.44	8.93	414.70	4.26	197.97
38	54.56	7.84	428.07	3.66	200.19
39	54.12	6.88	372.86	3.16	170.92
40	51.93	6.04	314.15	2.71	141.16
41	32.19	5.31	170.99	2.33	75.31
42	28.47	4.66	132.80	2.01	57.22
43	18.44	4.09	75.52	1.73	31.96
44	9.66	3.59	34.74	1.49	14.41
45	0.00	3.15	0.00	1.28	0.00
Total			2250.55		1038.37

The contribution made by different developmental stages towards the stable age-distribution of *A. janata* was determined and the results obtained are presented in Table 15 and Fig. 4. It could be seen that on reaching stable age-distribution, the population of *A. janata* in its various stages viz. egg, larva, pupa and adult contributed to the tune of 36.48, 57.14, 5.41 and 0.95 per cent, respectively.

Table 15. Stable age-distribution of *A. janata* on castor ($r_m = 0.1490$)

x	l_x	L_x	$e^{-r_m(x+1)}$	$\frac{L_x}{e^{-r_m(x+1)}}$	Per cent distribution	
1	2	3	4	5	6	
0	1.00	1.00	0.8615	0.8615	14.0124	
1	1.00	1.00	0.7423	0.7423	12.0736	36.48 eggs
2	1.00	1.00	0.6395	0.6395	10.4015	
3	1.00	1.00	0.5510	0.5510	8.9621	
4	1.00	1.00	0.4747	0.4747	7.7210	
5	1.00	1.00	0.4090	0.4090	6.6524	
6	1.00	1.00	0.3523	0.3523	5.7302	
7	1.00	1.00	0.3036	0.3036	4.9381	
8	1.00	1.00	0.2615	0.2615	4.2533	
9	1.00	0.99	0.2253	0.2231	3.6284	57.14 larvae
10	0.98	0.99	0.1941	0.1922	3.1261	

Table 15 contd.

1	2	3	4	5	6	
11	0.98	0.96	0.1672	0.1606	2.6121	
12	0.95	0.96	0.1441	0.1383	2.2423	
13	0.95	0.96	0.1241	0.1192	1.9388	
14	0.95	0.96	0.1069	0.1027	1.6704	
15	0.95	0.94	0.0921	0.0866	1.4085	
16	0.94	0.94	0.0794	0.0746	1.2133	
17	0.94	0.94	0.0684	0.0643	1.0459	
18	0.94	0.94	0.0589	0.0554	0.9010	
19	0.94	0.94	0.0507	0.0477	0.7758	
20	0.94	0.94	0.0437	0.0411	0.6684	
21	0.94	0.94	0.0377	0.0354	0.5757	
22	0.94	0.94	0.0324	0.0305	0.4960	
23	0.94	0.94	0.0279	0.0263	0.4277	5.41 pupae
24	0.94	0.94	0.0241	0.0226	0.3675	
25	0.94	0.94	0.0207	0.0195	0.3171	
26	0.94	0.94	0.0178	0.0168	0.2732	
27	0.94	0.94	0.0154	0.0144	0.2340	
28	0.94	0.94	0.0132	0.0124	0.2016	
29	0.94	0.94	0.0114	0.0107	0.1740	
30	0.94	0.94	0.0098	0.0092	0.1496	
31	0.94	0.94	0.0084	0.0079	0.1284	
32	0.94	0.94	0.0073	0.0068	0.1106	
33	0.94	0.94	0.0063	0.0059	0.0959	

Table 15 contd.

1	2	3	4	5	6	
34	0.94	0.94	0.0054	0.0051	0.0829	
35	0.94	0.94	0.0046	0.0044	0.0715	
36	0.94	0.94	0.0040	0.0037	0.0601	
37	0.99	0.99	0.0034	0.0032	0.0520	
38	0.94	0.94	0.0029	0.0028	0.0455	0.95 adults
39	0.94	0.93	0.0025	0.0023	0.0374	
40	0.92	0.91	0.0022	0.0020	0.0325	
41	0.90	0.89	0.0019	0.0017	0.0276	
42	0.88	0.84	0.0016	0.0013	0.0211	
43	0.81	0.74	0.0014	0.0010	0.0162	
44	0.67	0.57	0.0012	0.0004	0.0097	
45	0.47	0.47	0.0010	0.0004	0.0065	
Total				6.1481	99.9911	

4.3.2 Pomegranate

The life-tables and age-specific fecundity for *A. janata* when reared on pomegranate leaves are presented in Table 16 to 20.

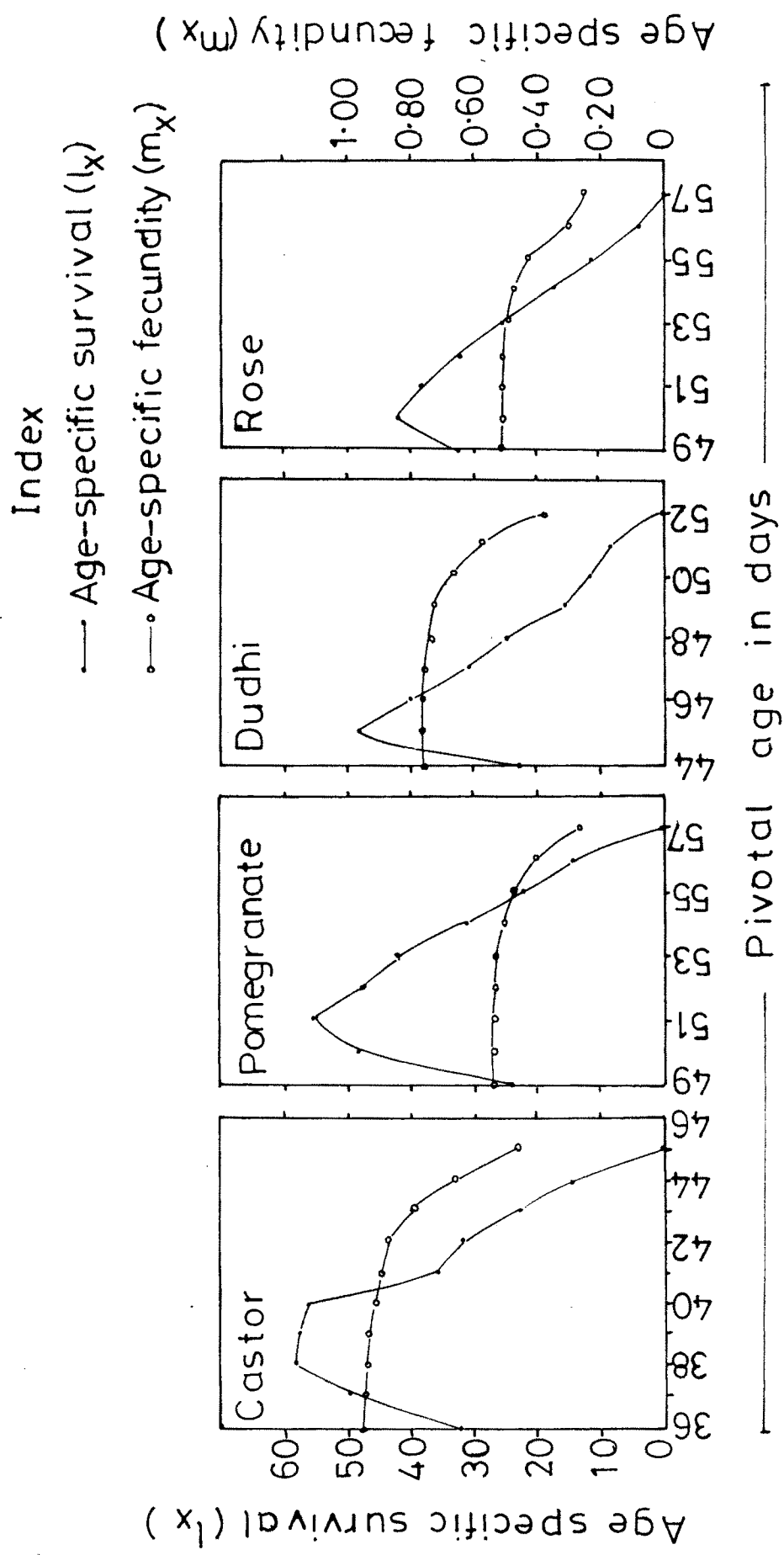


Fig2. Daily age specific survival and fecundity of A. janata on different hosts

Table 16. Survival of different life stages of *A. janata* during development on pomegranate

Sr. No.	Number of eggs kept	Number surviving			Sex	
		Egg period 0 - 2 days	Larval period 3 - 30 days	Pupal period 31-43 days	Male	Female
1	20	20	13	13	3	10
2	20	20	12	12	5	7
3	20	20	9	9	6	3
4	20	20	13	13	7	6
5	20	20	9	7	5	2
Total	100	100	56	54	26	28

Table 16 shows that the survival of *A. janata* was 100, 56 and 54 in respect of eggs, larvae and pupae in a cohort of 100 eggs. A cohort of 100 eggs resulted into the emergence of 26 males and 28 females.

Table 17. Life-fecundity table of *A. janata* on pomegranate

Pivotal age in (days)	Survival of female at different age interval	Age schedule for female birth		
x	l_x	m_x	$l_x m_x$	$l_x m_x x$
0-43	0.54	—	—	Immature stages
44-48	0.54	—	—	Pre-oviposition period
49	0.54	23.88	12.89	631.61
50	0.54	48.42	26.14	1307.34
51	0.54	55.57	30.00	1530.39
52	0.54	47.27	25.52	1352.86
53	0.54	42.27	22.82	1209.76
54	0.51	31.27	15.94	861.17
55	0.49	22.59	11.06	608.80
56	0.41	14.35	5.88	329.47
57	0.27	0.00	0.00	0.00

$$R_0 = \sum l_x m_x = 150.25$$

$$\sum l_x m_x x = 7831.40$$

It is evident from Table 17 and Fig. 2 that survival of immature stages (l_x) was 0.54 (based on one individual) per individual within a pivotal age of 43 days. The pre-oviposition period ranged from 44th to 48th days of pivotal age. The females contributed highest ($m_x = 55.57$) on 51st day of pivotal age. The first female mortality was noticed on 6th day ($l_x = 0.51$) from the first day of oviposition of adult when the culture was in the 54th day of pivotal age. The mortality of females increased slowly thereafter.

The females oviposited for 8 days. The net reproductive rate (R_0) representing the total female births was 150.25 females per female per generation on pomegranate.

Table 18 indicates the results on mean generation length, intrinsic rate of increase in numbers and finite rate of increase in number of *A. janata* on pomegranate. The mean generation time (T) was 51.14 days. The innate capacity for increase in numbers (r_m) was 0.0980 female per female per day with a daily finite rate of increase (λ) 1.10 females per female per day.

Table 13. Mean length of generation, innate capacity for increase in numbers and finite rate of increase in numbers of *A. janata* on pomegranate

Population growth statistics

Mean length of generation

$$T_c = \frac{\sum l_{x_m} x}{R_0} \quad 52.12 \text{ days}$$

Innate capacity for increase in numbers

$$r_c = \frac{\log_e R_0}{T_c} \quad 0.0962 \text{ female/female/day}$$

Arbitrary r_m 0.08 and 0.10

$$\text{corrected } r_m = \sum e^{T - r_m x} l_{x_m} x = 1096.6 \quad 0.0980 \text{ female/female/day}$$

(Arbitrary value changing at second decimal place, each one from lower and higher position)

Corrected generation time

$$T = \frac{\log_e R_0}{r_m} \quad 51.14 \text{ days}$$

Finite rate of increase in numbers

1.10 female/female/day

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

Table 19 indicated the data for calculation of corrected (r_m). The two trial values of 2614.24 and 930.62 were plotted on horizontal axis against on their respective arbitrary r_c i.e. 0.08 and 0.10 on vertical axis and corrected r_m was calculated by interpolation method. Thus, the corrected r_m was 0.0980 female per female per day (Fig. 3).

Table 19. Calculation of r_m of *A. janata* by trial and error method on pomegranate

Pivotal age (days)	$l_{x^m_x}$	$r_m = 0.08$		$r_m = 0.10$	
		$e^{7-r_m x}$	$e^{7-r_m x} l_{x^m_x}$	$e^{7-r_m x}$	$e^{7-r_m x} l_{x^m_x}$
44-48	—	—	—	Pre-oviposition period	
49	12.89	21.75	280.46	8.17	105.26
50	26.14	20.08	525.03	7.39	193.15
51	30.00	18.54	556.23	6.68	200.57
52	25.52	17.11	436.79	6.04	154.38
53	22.82	15.79	360.55	5.47	124.91
54	15.94	14.58	232.48	4.95	78.95
55	11.06	13.46	148.90	4.88	49.56
56	5.88	12.43	73.80	4.05	23.84
57	0.00	11.47	0.00	3.67	0.00
Total			2614.24		930.62

The contribution made by different developmental stages towards the stable age-distribution of *A. janata* was worked out when reared on pomegranate leaves and the results are presented in Table 20 and Fig. 4. On reaching stable age-distribution, a high proportion of immature stages (99.39 per cent) contributed in this theoretical population as apposed to adults (0.59 per cent).

Table 20. Stable age-distribution of *A. janata* on pomegranate

$$(r_m = 0.0980)$$

x	l_x	L_x	$e^{-r_m(x+1)}$	$L_x \cdot e^{-r_m(x+1)}$	Per cent distribution
1	2	3	4	5	6
0	1.00	1.00	0.9066	0.9066	10.9214
1	1.00	1.00	0.8220	0.8220	9.9023
2	1.00	0.98	0.7452	0.7303	8.7976
3	0.97	0.98	0.6757	0.6621	7.9760
4	0.97	0.98	0.6126	0.6003	7.2315
5	0.97	0.98	0.5554	0.5443	6.5569
6	0.97	0.98	0.5035	0.4935	5.9449
7	0.07	0.87	0.4565	0.3972	4.7849
8	0.78	0.87	0.4139	0.3601	4.3379
9	0.78	0.87	0.3753	0.3265	3.9332
10	0.78	0.87	0.3402	0.2960	3.5657

29.62
eggs

Table 2) contd.

1	2	3	4	5	6
11	0.78	0.76	0.3085	0.2344	2.8237
12	0.74	0.76	0.2797	0.2125	2.5599
13	0.74	0.76	0.2535	0.1927	2.3213
14	0.74	0.71	0.2299	0.1632	1.9660
15	0.68	0.71	0.2084	0.1480	1.7828
16	0.68	0.71	0.1890	0.1341	1.6154
17	0.68	0.67	0.1713	0.1148	1.3829
18	0.66	0.67	0.1553	0.1040	1.2528
19	0.66	0.64	0.1408	0.0901	1.0853
20	0.62	0.64	0.1277	0.0817	0.9842
21	0.62	0.61	0.1157	0.0706	0.8504
22	0.61	0.61	0.1049	0.0640	0.7709
23	0.61	0.60	0.0951	0.0571	0.6878
24	0.59	0.58	0.0862	0.0500	0.6023
25	0.58	0.58	0.0782	0.0453	0.5457
26	0.58	0.57	0.0709	0.0404	0.4866
27	0.57	0.57	0.0643	0.0366	0.4409
28	0.57	0.57	0.0583	0.0332	0.3999
29	0.57	0.56	0.0528	0.0296	0.3565
30	0.56	0.56	0.0479	0.0268	0.3228
31	0.56	0.56	0.0434	0.0243	0.2927
32	0.56	0.56	0.0393	0.0220	0.2650
33	0.56	0.55	0.0357	0.0196	0.2361
34	0.55	0.55	0.0323	0.0178	0.2144

67.57
larvae

Table 20 contd.

1	2	3	4	5	6	
35	0.55	0.55	0.0293	0.0161	0.1939	
36	0.55	0.55	0.0266	0.0146	0.1758	2.21 pupae
37	0.55	0.55	0.0241	0.0132	0.1590	
38	0.55	0.54	0.0218	0.0118	0.1421	
39	0.54	0.54	0.0198	0.0107	0.1288	
40	0.54	0.54	0.0179	0.0097	0.1163	
41	0.54	0.54	0.0163	0.0088	0.1060	
42	0.54	0.54	0.0147	0.0079	0.0951	
43	0.54	0.54	0.0134	0.0072	0.0867	
44	0.54	0.54	0.0121	0.0065	0.0783	
45	0.54	0.54	0.0110	0.0059	0.0710	
46	0.54	0.54	0.0099	0.0053	0.0638	
47	0.54	0.54	0.0090	0.0048	0.0578	
48	0.54	0.54	0.0082	0.0044	0.0530	
49	0.54	0.54	0.0074	0.0040	0.0481	
50	0.54	0.54	0.0067	0.0036	0.0433	0.59 adults
51	0.54	0.54	0.0061	0.0033	0.0397	
52	0.54	0.54	0.0055	0.0029	0.0349	
53	0.54	0.52	0.0050	0.0026	0.0313	
54	0.51	0.50	0.0045	0.0022	0.0265	
55	0.49	0.45	0.0041	0.0018	0.0216	
56	0.41	0.34	0.0037	0.0012	0.0144	
57	0.27	0.27	0.0033	0.0009	0.0108	
Total				8.3011	99.9973	

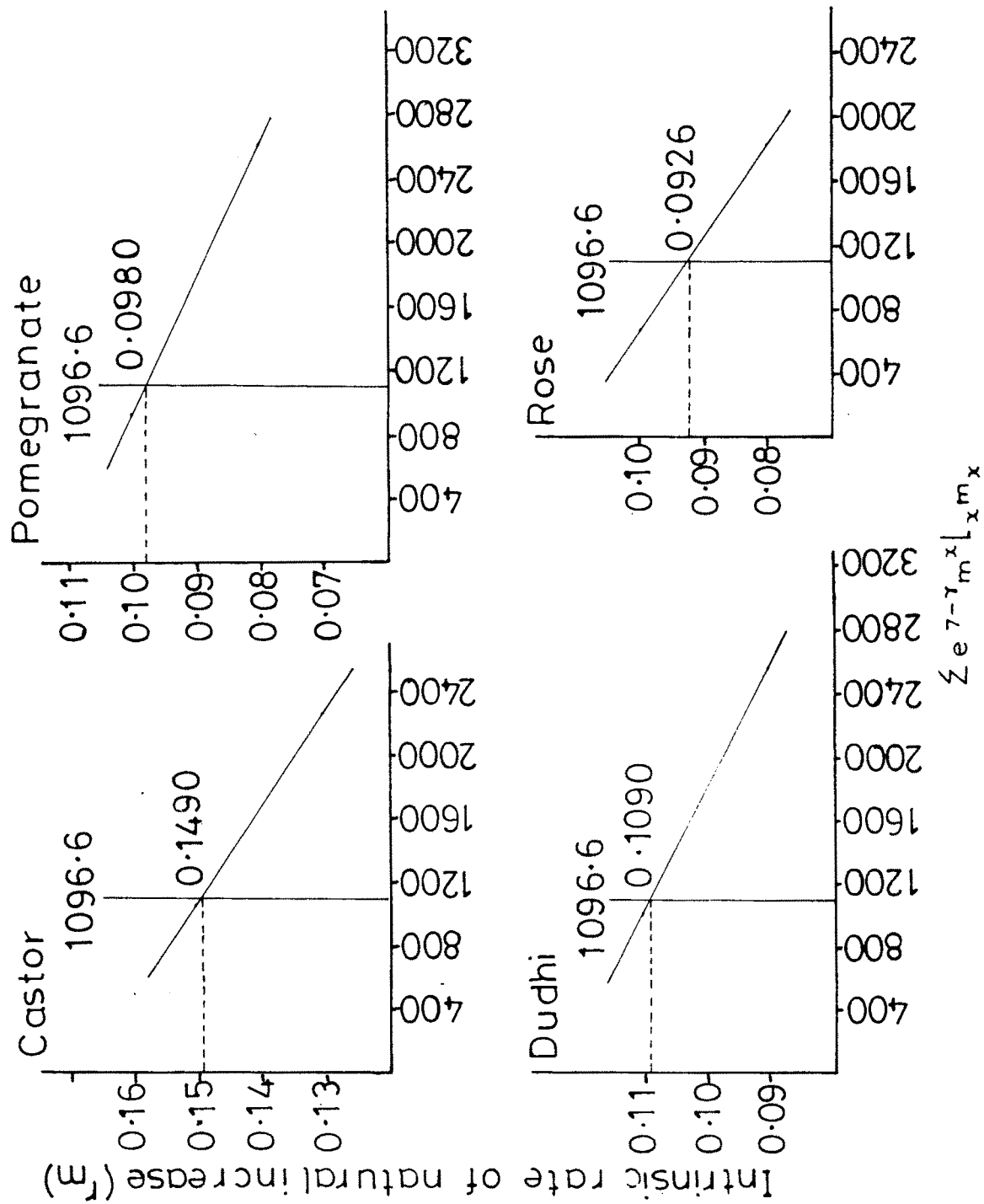


Fig 3. Determination of the intrinsic rate of increase (r_m) of A.janata on different hosts

4.3.3 Euphorbia sp

The data regarding the survival of life stages for A. janata when reared on dudhi leaves are summarised from Table 21 to 25.

Table 21 indicated that the survival of A. janata was 100, 80 and 76 in respect of eggs, larvae and pupae in cohort of 100 eggs. There was successful emergence of 35 males and 41 females on dudhi.

Table 21. Survival of different life stages of A. janata during development of dudhi.

Sr. No.	Number of eggs kept	Number surviving			Sex	
		Egg period 0 - 2 days	Larval period 3 - 24 days	Pupal period 25-36 days	Male	Female
1.	20	20	18	18	9	9
2.	20	20	17	16	8	8
3.	20	20	16	15	6	9
4.	20	20	13	13	5	8
5.	20	20	16	14	7	7
Total	100	100	80	76	35	41

Table 22. Life-fecundity table of *A. janata* on Euphorbia sp.

Pivotal age in (days)	Survival of females at different age intervals	Age schedule for female birth		
x	l_x	m_x	$l_x m_x$	$l_x m_x x$
0-36	0.76	—	—	Immature stages
37-43	0.76	—	—	Pre-oviposition period
44	0.76	23.65	17.97	790.85
45	0.76	48.35	36.74	1653.57
46	0.76	40.09	30.46	1401.54
47	0.76	31.56	23.96	1127.32
48	0.74	25.34	18.75	900.07
49	0.73	15.65	11.42	559.80
50	0.67	11.50	7.70	385.25
51	0.58	8.35	4.84	246.99
52	0.38	0.00	0.00	0.00

$$\begin{aligned}
 R_0 &= \sum l_x m_x & \leq l_x m_x x \\
 &= 151.84 & = 7065.39
 \end{aligned}$$

It is clear from the Table 22 and Fig. 2 that the survival of immature stages (l_x) was 0.76 per cent individual within a pivotal age of 36th day. The pre-oviposition period ranged from 37th to 43rd day of

pivotal age. The female contributed highest ($m_x = 48.35$) on 45th day of pivotal age. The first female mortality was observed on 4th day ($l_x = 0.74$) from the first day of oviposition of adult, when the culture was in the 48th day of pivotal age. The female mortality increased slowly thereafter. The females oviposited for 8 days. The net reproductive rate (R_0) was 151.84 females per female per generation.

Table 23 reveals the results on mean generation length, intrinsic rate of increase in numbers and finite rate of increase in numbers of *A. janata* on dudhi. The mean generation time (T) was 46.08 days. The innate capacity of increase in numbers (r_m) was 0.1090 female per female per day with a daily finite rate of increase (λ) 1.10 females per female per day.

The data for calculation of corrected r_m are presented in Table 24 and Fig. 3. The two trial values viz. 2565.21 and 1013.32 were used for calculation of corrected r_m . Thus, the corrected r_m was 0.1090 female per female per day.

The stable age-distribution of *A. janata* was worked out when reared on dudhi leaves and results are presented in Table 25 and Fig. 4. On reaching stable age distribution, the populations of *A. janata* in its various stages viz. the egg, larva, pupa and adult contributed to the tune of 31.01, 63.57, 4.21 and 1.19 per cent, respectively.

Table 23. Mean length of generation, innate capacity for increase in numbers and finite rate of increase in numbers of *A. janata* on Euphorbia sp

Population growth statistics

Mean length of generation

$$T_c = \frac{\sum l_{xm} x}{R_0} \quad 46.53 \text{ days}$$

Innate capacity for increase in numbers

$$r_c = \frac{\log_e R_0}{T_c} \quad 0.1079 \text{ female/} \\ \text{female/day}$$

Arbitrary r_m 0.09 and 0.11

$$\text{corrected } r_m \leq e^{1-r_m} l_{xm} x = 1096.6 \quad 0.1090 \text{ female/} \\ \text{female/day}$$

(Arbitrary value changing at second decimal place, each one from lower and higher position)

Corrected generation time

$$T = \frac{\log_e R_0}{r_m} \quad 46.08 \text{ days}$$

Finite rate of increase in numbers

1.11 females/
female/day

$$\lambda = \text{anti } \log_e r_m$$

Table 24. Calculation of r_m of *A. janata* by trial and error method on *Euphorbia* sp

Pivotal age (days)	$l_{x^m_x}$	$r_m = 0.09$		$r_m = 0.11$	
		$e^{7-r_m x}$	$e^{7-r_m x} l_{x^m_x}$	$e^{7-r_m x}$	$e^{7-r_m x} l_{x^m_x}$
37-43	—	—	—	Pre-oviposition period	
44	17.97	20.90	375.66	8.67	155.83
45	36.74	19.10	701.95	7.76	285.39
46	30.46	17.46	531.87	6.96	211.96
47	23.96	15.96	382.36	6.23	149.36
48	18.75	14.58	273.47	5.53	104.71
49	11.42	13.32	152.22	5.00	57.13
50	7.70	12.18	93.80	4.48	34.51
51	4.84	11.13	53.83	4.01	19.43
52	0.00	10.17	0.00	3.59	0.00
Total			2565.21		1018.32

Table 25. Stable age-distribution of *A. janata* on
Euphorbia sp
 ($r_m = 0.1090$)

x	l_x	L_x	$e^{-r_m(x+1)}$	$L_x \cdot e^{-r_m(x+1)}$	Per cent distrib- ution	
1	2	3	4	5	6	
0	1.00	1.00	0.8967	0.8967	11.4814	
1	1.00	1.00	0.8041	0.8041	10.2957	31.01 eggs
2	1.00	1.00	0.7210	0.7270	9.2317	
3	0.96	0.98	0.6466	0.6336	8.1126	
4	0.94	0.92	0.5798	0.5334	6.8297	
5	0.91	0.90	0.5199	0.4679	5.9910	
6	0.90	0.88	0.4662	0.4103	5.2535	
7	0.87	0.86	0.4181	0.3595	4.6030	
8	0.86	0.86	0.3749	0.3224	4.1280	
9	0.86	0.86	0.3362	0.2891	3.7016	
10	0.86	0.85	0.3014	0.2562	3.2804	
11	0.85	0.83	0.2703	0.2243	2.8719	
12	0.81	0.83	0.2424	0.2012	2.5716	
13	0.81	0.83	0.2174	0.1804	2.3098	63.57 larvae
14	0.81	0.83	0.1949	0.1618	2.0717	
15	0.81	0.83	0.1748	0.1451	1.8578	
16	0.81	0.83	0.1567	0.1301	1.6658	
17	0.81	0.83	0.1405	0.1166	1.4529	
18	0.81	0.83	0.1260	0.1046	1.3393	
19	0.81	0.83	0.1130	0.0938	1.2010	
20	0.81	0.83	0.1013	0.0841	1.0768	
21	0.81	0.83	0.0908	0.0754	0.9654	

Table 25 contd.

1	2	3	4	5	6	
22	0.81	0.83	0.0815	0.0676	0.8693	
23	0.81	0.80	0.0730	0.0584	0.7477	
24	0.80	0.80	0.0655	0.0524	0.6709	
25	0.80	0.80	0.0587	0.0470	0.6017	
26	0.80	0.80	0.0527	0.0421	0.5660	
27	0.79	0.79	0.0472	0.0373	0.4775	
28	0.79	0.79	0.0423	0.0334	0.4276	4.21 pupae
29	0.79	0.79	0.0380	0.0300	0.3841	
30	0.79	0.79	0.0340	0.0269	0.3444	
31	0.79	0.79	0.0305	0.0241	0.2085	
32	0.79	0.78	0.0274	0.0213	0.2727	
33	0.78	0.77	0.0245	0.0189	0.2419	
34	0.76	0.77	0.0220	0.0169	0.2163	
35	0.76	0.77	0.0197	0.0152	0.1946	
36	0.76	0.77	0.0177	0.0136	0.1741	
37	0.76	0.77	0.0158	0.0122	0.1562	
38	0.76	0.77	0.0142	0.0109	0.1395	
39	0.76	0.77	0.0127	0.0098	0.1254	
40	0.76	0.77	0.0114	0.0088	0.1126	
41	0.76	0.77	0.0102	0.0079	0.1011	
42	0.76	0.77	0.0092	0.0070	0.0896	
43	0.76	0.77	0.0082	0.0063	0.0806	1.19 adults
44	0.76	0.77	0.0074	0.0057	0.0729	

Table 25 contd.

1	2	3	4	5	6
45	0.76	0.77	0.0066	0.0051	0.0653
46	0.76	0.77	0.0059	0.0045	0.0576
47	0.76	0.075	0.0053	0.0040	0.0512
48	0.74	0.73	0.0047	0.0034	0.0435
49	0.73	0.70	0.0042	0.0030	0.0384
50	0.67	0.62	0.0038	0.0023	0.0294
51	0.58	0.48	0.0034	0.0016	0.0204
52	0.38	0.38	0.0030	0.0011	0.0140
Total				7.8100	99.9876

4.3.4 Rose

The data pertaining to life-tables and age-specific fecundity for *A. janata* when reared on rose leaves are presented from Table 26 to 30.

The results in Table 26 indicated that the survival of eggs, larvae and pupae of *A. janata* was 100, 55, and 51 per cent, respectively. A cohort of 100 eggs resulted into the emergence of 21 males and 30 females.

Table 26. Survival of different life stages of *A. janata* during development on rose

Sr. No.	Number of eggs kept	Number surviving			Sex	
		Egg period 0 - 2 days	Larval period 3 - 29 days	Pupal period 30-43 days	Male	Female
1	20	20	9	5	1	4
2	20	20	8	8	3	5
3	20	20	14	14	7	7
4	20	20	14	11	4	7
5	20	20	13	13	6	7
Total	100	100	55	51	21	30

It seems from the Table 27 and Fig. 2 that the survival of immature stages (l_x) was 0.51 per individual within a pivotal age of 43 days. The pre-oviposition period ranged from 44th to 48th day of pivotal age. The female births was highest ($m_x = 42.72$) on second day of oviposition on 50th day of pivotal age and it decreased slowly thereafter. The first female mortality was observed on 5th day ($l_x = 10.51$) after the start of oviposition when the culture was in the 53rd day of pivotal age. The females oviposited for 8 days. The net reproductive rate (R_0) was 101.98 females per generation. Thus, the population of *A. janata* would be able to multiply 101.98 times per generation on rose.

Table 27. Life-fecundity table of *A. janata* on rose

Pivotal age (days)	Survival of female at different age interval	Age schedule for female birth		
x	l_x	m_x	$l_x m_x$	$l_x m_x x$
0-43	0.51	—	—	Immature stages
44-48	0.51	—	—	Pre-oviposition period
49	0.51	31.96	16.29	798.68
50	0.51	42.72	21.78	1089.36
51	0.51	38.54	19.65	1002.42
52	0.51	32.92	16.78	873.03
53	0.50	25.72	12.86	681.58
54	0.48	17.59	8.44	455.93
55	0.43	11.52	4.95	272.44
56	0.30	4.12	1.23	69.21
57	0.26	0.00	0.00	0.00

$$R_0 \leq l_x m_x = 101.98$$

$$\leq l_x m_x x = 5242.65$$

Index

Egg

Larva

Pupa

Adult

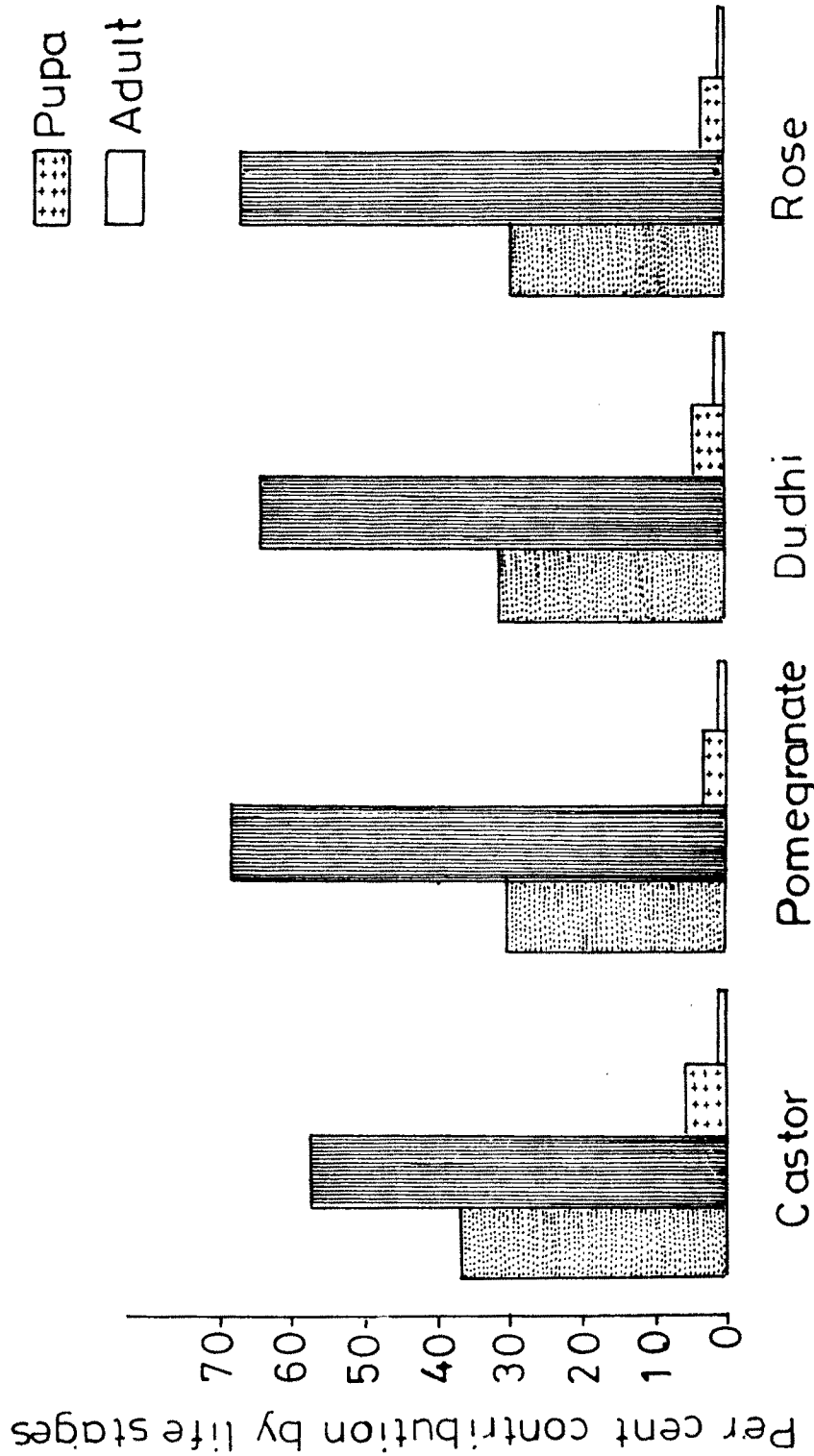


Fig4. Per cent individuals in the stable age-distribution of A.janata on different hosts

Table 28 indicated the results on mean length of generation, intrinsic rate of increase in numbers and finite rate of increase in numbers of *A. janata* on rose. The corrected generation time was 49.94 days while the finite rate of increase in numbers (λ) was 1.09 females per female per day. The intrinsic rate of natural increase in numbers of *A. janata* was 0.0926 female per female per day on rose.

The corrected r_m was calculated by interpolation method (Table 29 and Fig. 3). Thus, the corrected r_m was calculated as 0.0926 female per female per day.

The contribution made by different developmental stages towards the stable age-distribution of *A. janata* was determined and the results obtained are presented in Table 30 and Fig. 4. It could be seen that on reaching stable age-distribution, the population of *A. janata* in its various stages viz. egg, larva, pupa and adult contributed to the tune of 29.87, 66.48, 2.92 and 0.72 per cent, respectively.

Table 28. Mean length of generation, innate capacity for increase in numbers and finite rate of increase in numbers of *A. janata* on rose

Population growth statistics

Mean length of generation

$$T_c = \frac{\sum l_x m_x}{R_0} \quad 51.41 \text{ days}$$

Innate capacity for increase in numbers

$$r_c = \frac{\log_e R_0}{T_c} \quad 0.0900 \text{ female/female/day}$$

Arbitrary r_m 0.08 and 0.10
 corrected $r_m \leq e^{7-r_m} l_x m_x = 1096.6$

0.0926 female/female/day

(Arbitrary value changing at second decimal place, each one from lower and higher position)

Corrected generation time

$$T = \frac{\log_e R_0}{r_m} \quad 49.94 \text{ days}$$

Finite rate of increase in numbers

$$\lambda = \text{anti log}_e r_m \quad 1.09 \text{ female/female/day}$$

Table 29. Calculation of r_m of *A. janata* by trial and error method on rose

Pivotal age (days)	$l_{x^m_x}$	$r_m = 0.08$		$r_m = 0.10$	
		$e^{7-r_m x}$	$e^{7-r_m x} l_{x^m_x}$	$e^{7-r_m x}$	$e^{7-r_m x} l_{x^m_x}$
44-48	—	—	—	—	—
49	16.29	21.75	354.44	8.16	133.02
50	21.78	20.08	437.46	7.38	160.93
51	19.65	18.54	364.33	6.68	131.37
52	16.78	17.11	287.20	6.05	101.51
53	12.86	15.78	203.18	5.47	70.39
54	8.44	14.58	123.09	4.95	41.80
55	4.95	13.46	66.64	4.48	22.18
56	1.23	12.42	15.28	4.05	4.98
57	0.00	11.00	0.00	3.66	0.00
Total			1851.62		666.18

Table 30. Stable age-distribution of *A. janata* on rose

$$(r_m = 0.0926)$$

x	l_x	L_x	$e^{-r_m(x+1)}$	$L_x \cdot e^{-r_m(x+1)}$	Per cent distrib- ution
1	2	3	4	5	6
0	1.00	1.00	0.9115	0.9115	10.8908
1	1.00	1.00	0.8309	0.8309	9.9278
2	1.00	1.00	0.7574	0.7574	9.0496
3	1.00	1.00	0.6904	0.6904	8.2490
4	1.00	1.00	0.6293	0.6293	7.5190
5	0.98	0.99	0.5737	0.5679	6.7854
6	0.98	0.92	0.5229	0.4811	5.7493
7	0.87	0.79	0.4667	0.3766	4.4997
8	0.72	0.79	0.4345	0.3433	4.1018
9	0.72	0.79	0.3961	0.3129	3.7386
10	0.72	0.63	0.3611	0.2274	2.7170
11	0.55	0.63	0.3291	0.2073	2.4768
12	0.55	0.63	0.3000	0.1890	2.2582
13	0.55	0.63	0.2735	0.1725	2.0586
14	0.55	0.63	0.2493	0.1570	1.8758
15	0.55	0.63	0.2272	0.1431	1.7098
16	0.55	0.63	0.2071	0.1305	1.5592
17	0.55	0.63	0.1888	0.1189	1.4206
18	0.55	0.63	0.1721	0.1084	1.2951
19	0.55	0.63	0.1569	0.0988	1.1804

29.87
eggs66.48
larvae

Table 30 contd.

1	2	3	4	5	6
20	0.55	0.63	0.1430	0.0901	1.0765
21	0.55	0.63	0.1303	0.0821	0.9809
22	0.55	0.63	0.1188	0.0748	0.8937
23	0.55	0.63	0.1083	0.0682	0.8148
24	0.55	0.63	0.0987	0.0622	0.7431
25	0.55	0.63	0.0900	0.0567	0.6774
26	0.55	0.63	0.0820	0.0517	0.6177
27	0.55	0.63	0.0748	0.0471	0.5627
28	0.55	0.63	0.0681	0.0429	0.5125
29	0.55	0.55	0.0621	0.0341	0.4074
30	0.55	0.55	0.0566	0.0311	0.3715
31	0.55	0.55	0.0516	0.0284	0.3393
32	0.55	0.54	0.0470	0.0254	0.3034
33	0.54	0.54	0.0429	0.0231	0.2760
34	0.54	0.53	0.0391	0.0207	0.2473
35	0.53	0.52	0.0356	0.0185	0.2210
36	0.52	0.51	0.0325	0.0165	0.0971
37	0.51	0.51	0.0296	0.0151	0.1804
38	0.51	0.51	0.0270	0.0137	0.1636
39	0.51	0.51	0.0246	0.0125	0.1493
40	0.51	0.51	0.0224	0.0114	0.1362
41	0.51	0.51	0.0204	0.0104	0.1242
42	0.51	0.51	0.0186	0.0095	0.1135
43	0.51	0.51	0.0170	0.0086	0.1027

2.92
pupae

Table 3) contd.

1	2	3	4	5	6	
44	0.51	0.51	0.0154	0.0079	0.0943	
45	0.51	0.51	0.0141	0.0072	0.0860	
46	0.51	0.51	0.0128	0.0065	0.0776	
47	0.51	0.51	0.0117	0.0059	0.0704	
48	0.51	0.51	0.0107	0.0054	0.0645	
49	0.51	0.51	0.0097	0.0049	0.0585	
50	0.51	0.51	0.0088	0.0045	0.0537	0.72 adults
51	0.51	0.51	0.0081	0.0041	0.0489	
52	0.51	0.50	0.0073	0.0036	0.0430	
53	0.50	0.49	0.0067	0.0033	0.0358	
54	0.48	0.45	0.0061	0.0027	0.0322	
55	0.43	0.36	0.0055	0.0020	0.0238	
56	0.30	0.28	0.0051	0.0014	0.0167	
57	0.26	0.26	0.0046	0.0012	0.0143	
Total				8.3694	99.9934	

4.4 Field life-tables, key mortality factors and preparation of budgets

Field life-tables and key mortality factors of *A. janata* were studied on castor variety VI-9 during the year 1985-86 and 1986-87. The results obtained in the present investigation are presented on the basis of each generation for two successive seasons.



Infested Castor field by Achaea Janata Larvae



Parasitised Larvae of A. janata by
Microplitis maculipennis

Table 31. Key mortality factors for first generation of *A. janata* on castor during 1985-86, population/hectare

Age interval	Number alive at the begin- ning of x	Factors respon- sible for d _x	Number dying during x	d _x as a % of l _x	Sur- val rate
x	l _x	d _x F	d _x	100 q _x	s _x
Expected eggs	43,823	Sterility/ dead	6,573	14.99	0.85
Viable egg	37,250	--			
Larval instars:					
Early instars (I - III)(N ₁)	37,250	<i>M. maculi- pennis</i>	500	1.34	0.97
		Unknown causes	4,125	11.07	
Late instars (IV - V)	32,625	Unknown causes	1,250	3.83	0.96
Pupa	31,375	Unknown causes	625	2.00	0.98
Moths	30,750	Sex 50% females			1.00
Females x ² (N ₃)	30,750	Reprodu- cing females	15,375		
Actual number of younger larvae in next genera- tion (N ₂)					
1,67,875					
Trend index (I) = $\frac{N_2}{N_1}$		4.506			
Generation survival (SG) = N_3/N_1		0.82			

It seems from Table 31 that there was 14.38 per cent mortality among the eggs owing to sterility in first generation. The larval mortality because of parasite, Microplitis maculipennis (Szépligeti) (Braconidae: Hymenoptera) was 1.34 per cent. The mortality of early and late instar larve because of unknown reasons causes was 11.07 and 3.83 per cent, respectively.

The generation survival value on castor was 0.82. The positive value of trend index (4.506) indicated that the mortality factors operating during first generation were not effective in causing a decline in the pest population in next generation on castor.

Table 32. Budget of A. janata during first generation 1985-86 (31 to 35 meteorological week)

Age interval	Number/ha	log number/ha	k's
Expected eggs	43,823	4.6417	—
Viable eggs	37,250	4.5711	0.0706
Actual early instar larvae after mortality due to parasite and unknown causes	37,250	4.5711	0.0000
Late instar after mortality due to unknown causes	32,650	4.5138	0.0573
Pupae after mortality due to unknown causes	31,375	4.4965	0.0173
Moths	30,750	4.4878	0.0087
Reproducing females	15,375	4.1863	0.3010
			K = 0.4549

The results in Table 32 and Fig. 5 indicates that the maximum mortality was occurred in the early instar larvae during first generation (31 to 35 meteorological week), the 'k' value for this stage being the highest (0.0573). The total k's for all life stages remained $K = 0.4549$. The number of reproducing females per hectare during first generation were 15,375, which actually contributed for population build up in second generation.

It seen from Table 33 that there was 11.39 per cent mortality of eggs because of sterility. The parasitization of larvae because of M. maculipennis was 4.91 per cent. The larval mortality owing to unknown causes in early and late instars was 4.61 and 2.05 per cent, respectively. The generation survival value was 0.88. The negative value of trend index (0.301) indicated that the mortality factors operating during this period were effective in checking the pest population in next generation.

It is evident from the Table 34 and Fig. 5 that the early instar larvae had highest mortality ($k = 0.0435$) in second generation (36 to 40 meteorological week). The next important mortality factor was in pupal stage (0.0090). The total of k's for all the life stages remained $K = 0.4091$. At the end of second generation, 73,875 females were expected to contribute for population build up in third generation.

Table 33. Key mortality factors for second generation of *A. janata* on castor during 1985-86, population/hectare

Age interval	Number alive at the begin- ning of x	Factors re- sponsible for d_x	Number dying during x	d_x as a % of l_x	Sur- vival rate
x	l_x	d_x^F	d_x	100 q_x	S_x
Expected eggs	1,89,475	Sterility/ dead	21,600	11.39	0.88
Viable eggs	1,67,875	—			
Larval instars:					
Early instars (N_1) (I - III)	1,67,875	<i>M. maculipennis</i>	8,250	4.91	0.90
		Unknown causes	7,750	4.61	—
Late instars (IV - V)	1,51,875	Unknown causes	3,125	2.05	0.98
Pupae	1,48,750	Unknown causes	1,000	0.67	0.99
Moths	1,47,750	Sex 50% females			1.00
Female x^2 (N_3)	1,47,750	Reprodu- cing females	73,875		
Actual number of younger lar- vae in next generation (N_2)	4,766				
Trend index (I)	$= N_2/N_1$		0.301		
Generation survival (SG)	$= N_3/N_1$		0.88		

Table 34. Budget of *A. janata* during second generation, 1985-86 (36 to 40 meteorological week)

Age interval	Number/ha	Log number/ha	k's
Expected eggs	1,89,475	5.2775	--
Viable eggs	1,67,875	5.2249	0.0526
Actual early instar larvae after mortality due to parasite and unknown causes	1,67,875	5.2249	0.0000
Late instars after mortality due to unknown causes	1,51,875	5.1814	0.0435
Pupae after mortality due to unknown causes	1,48,750	5.1724	0.0090
Moths	1,47,750	5.1695	0.0029
Reproducing females	73,875	4.8684	0.3011
			$K = 0.4091$

It is observed from Table 35 that mortality of eggs due to sterility was 10.49 per cent in third generation (41 to 44 meteorological week). The mortality of early instar larvae by *M. maculipennis* parasite was 22.02 per cent. The mortality of early and late instar larvae because of unknown causes was 1.74 and 0.92 per cent. The mortality was 1.39 per cent in the pupal stage.

Table 35. Key mortality factors for third generation of *A. janata* on castor during 1985-86, population/ hectare

Age interval	Number alive at the begin- ning of x	Factors respon- sible for d_x	Number dying during x	d_x as a % of l_x	Sur- vival rate
x	l_x	d_x^F	d_x	100 q_x	S_x
Expected eggs	53,258	Sterility/ dead	5,592	10.49	0.89
Viable eggs	47,666	—			
Larval instars:					
Early instars (N_1)					
(I - III)	47,666	<u>M. maculi-</u> <u>pennis</u>	10,500	22.02	0.76
		Unknown causes	833	1.74	
Late instars (IV - V)					
	36,333	Unknown causes	333	0.92	0.99
Pupae					
	36,000	Unknown causes	500	1.39	0.99
Moths					
	35,500	Sex 50% females			1.00
Female x^2 (N_3)	35,500	Reproducing females	17,750		
Actual number of younger larvae in next genera- tion (N_2)					
75,500					
Trend index (I)	$= N_2/N_1$		1.583		
Generation survival	$= N_3/N_1$		0.74		

Total mortality in larval and pupal stage because of unknown causes was 4.05 per cent. The generation survival value was 0.74. The trend index value (1.583) indicated that the mortality factors (major parasite) operating during this period were not effective in suppressing the pest population on castor.

The budget showing the age-specific key mortality factors (Table 36 and Fig. 5) indicates that maximum contribution towards generation mortality came from the early instar larvae ($k = 0.1179$). The total k 's for all the life stages was $K = 0.4772$.

Table 36. Budget of *A. janata* during third generation, 1985-86 (41 to 44 meteorological week)

Age interval	Number/ha	Log number/ha	k 's
Expected eggs	53,258	4.7263	—
Viable eggs	47,666	4.6782	0.0481
Actual early instar larvae after mortality due to parasite and unknown causes	47,666	4.6782	0.0000
Late instars after mortality due to unknown causes	36,333	4.5603	0.1179
Pupae after mortality due to unknown causes	36,000	4.5563	0.0040
Moths	35,500	4.5502	0.0061
Reproducing females	17,750	4.2491	0.3011
			$K = 0.4772$

Table 37. Key mortality factors for fourth generation of *A. janata* on castor during 1985-86, population/hectare

Age interval	Number alive at the begin- ning of x	Factors responsible for d_x	Number dying during x	d_x as a % of l_x	Sur- vival rate
x	l_x	d_x^F	d_x	100 q_x	S_x
Expected eggs	87,790	Sterility/ dead	12,290	13.99	0.86
Viable eggs	75,500	--			
Larval instars:					
Early instars (N_1)					
(I - III)	75,500	<u>M. maculi-</u> <u>pennis</u>	33,000	43.70	0.54
		Unknown causes	2,000	2.65	
Late instars (IV - V)	40,500	Unknown causes	875	2.16	0.98
Pupae	39,625	Unknown causes	250	0.63	0.99
Moths	39,375	Sex 50% females			1.00
Female x^2 (N_3)	39,375	Reproducing females	19,687.5		
Actual number of younger larvae in next genera- tion (N_2)					
Trend index (I) = N_2/N_1					
Generation survival (SG) = N_3/N_1					
					0.52

The mortality of eggs due to sterility was 13.99 per cent (Table 37). The parasite, *M. maculipennis* parasitized the early instar larvae to the extent of 43.70 per cent in last generation (45 to 49 meteorological week) for the year 1985-86. The mortality because of unknown causes was 2.65 and 2.16 per cent in early and last instar larvae. The pupal mortality due to unknown causes was 0.63 per cent. The total mortality in larval and pupal stage due to unknown causes was 5.44 per cent. The generation survival value was 0.52. The trend index value remained nil in the last generation.

The budget showing the age-specific key mortality factors (Table 38 and Fig. 5) indicates that the maximum contribution towards the generation mortality was of the early instar larvae ($k = 0.2705$). The total of k 's for all the life stages of pest remained $K = 0.6522$.

Table 38. Budget of *A. janata* during fourth generation, 1985-86 (45 to 49 meteorological week)

Age interval	Number/ha	Log number/ha	k's
Expected eggs	87,790	4.9434	—
Viable eggs	75,500	4.8750	0.0684
Actual early instar larvae after mortality due to parasite and unknown causes	75,500	4.8750	0.0000
Late instars after mortality due to unknown causes	40,500	4.6074	0.2705
Pupae after mortality due to unknown causes	39,625	4.5979	0.0095
Moths	39,375	4.5952	0.0027
Reproducing females	19,687	4.2941	0.3011
			$K = 0.6522$

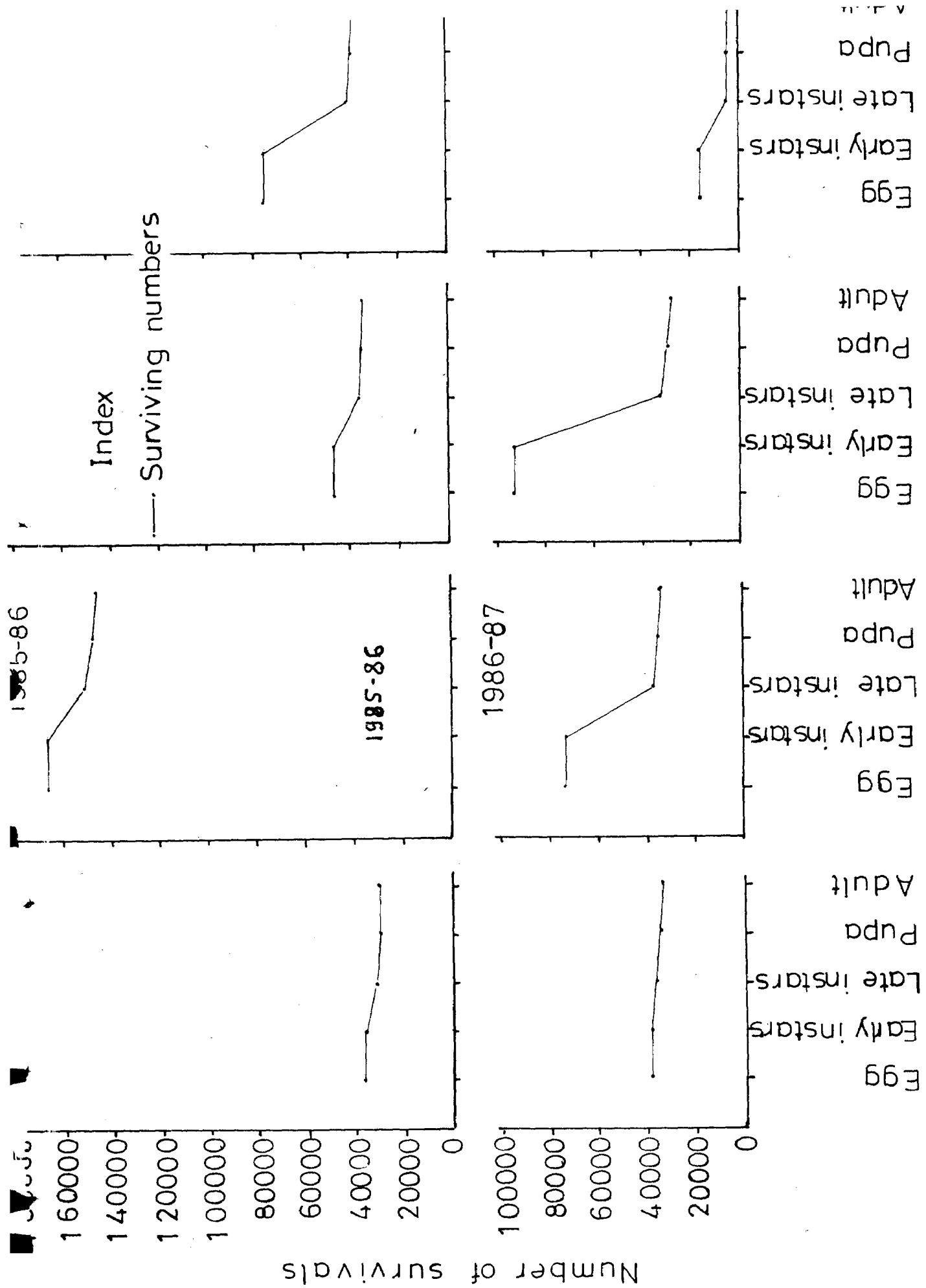


Fig5. Survivorship curve of *A. janata* during four generations on castor (1985-86 - 1986-87)

The age-specific life-tables were studied for four generations for the year 1986-87 and the results are presented from Table 39 to 46. The incidence of A. janata was noticed in the last week of July, 1986. The data presented in Table 39 for first generation reveals that there was 14.99 per cent mortality of eggs because of sterility. The parasitization of A. janata larvae by M. maculipennis was not observed during first generation (30 to 34 meteorological week). There was 5.73 and 4.73 per cent mortality of early and late instar larvae because of unknown reasons. The pupal mortality due to unknown reasons was 2.13 per cent. The sum of mortality in two life stages owing to unknown causes was 12.59 per cent. The survival value for the said generation remained 0.87. The positive value of trend index (1.869) revealed that the mortality factors that operated during first generation were not effective in causing decline in the pest population in next generation.

The perusal of age-specific mortalities (Table 40 and Fig. 5) shows that the maximum contribution towards the generation mortality was of the early instar larvae owing to unknown causes ($k = 0.0256$). The sum of the k 's for all the life stages was $K = 0.4277$. At the end of first generation for the year 1986-87, 17,250 females contributed towards population multiplication in second generation.

Table 39. Key mortality factors for first generation of *A. janata* on castor during 1986-87, population/hectare

Age interval	Number alive at the beginning of x	Factors respon- sible for d_x	Number dying during x	d_x as a % of l_x	Sur- vival rate
x	l_x	d_x^F	d_x	100 q_x	s_x
Expected eggs	46,176	Sterility/ dead	6,926	14.99	0.85
Viable eggs	39,250				
Larval instars:					
Early instars (N_1)					
(I - III)	39,250	<i>M. maculipennis</i>	-	-	-
		Unknown causes	2,250	5.73	0.94
Last instars (IV - V)	37,000	Unknown causes	1,750	4.73	0.95
Pupae	35,250	Unknown causes	750	2.13	0.93
Moths	34,500	Sex 50% females			1.00
Females x^2 (N_3)	34,500	Reproducing females	17,250		
Actual number of younger lar- vae in next generation (N_2)					
73,375					
Trend index	$= N_2/N_1$			1.869	
Generation survival (SG)	$= N_3/N_1$			0.87	

Table 40. Budget of *A. janata* during first generation, 1936-37 (30 to 34 meteorological week)

Age interval	Number/ha	Log number/ha	k's
Expected eggs	46,176	4.6644	—
Viable eggs	39,250	4.5938	0.0706
Actual early instar larvae after mortality due to parasite and unknown causes	39,250	4.5938	0.0000
Late instars after mortality due to unknown causes	37,000	4.5682	0.0256
Pupae after mortality due to unknown causes	35,250	4.5471	0.0211
Moths	34,500	4.5378	0.0093
Reproducing females	17,250	4.2367	0.3011
			K = 0.4277

The results on key mortality factors for second generation (35 to 39 meteorological week) of *A. janata* are summarised in Table 41. The mortality among the eggs, owing to sterility was 11.39 per cent. There was 44.12 per cent parasitization of early instar larvae by *M. maculipennis*. The mortality due to unknown causes in early and late instar was 5.62 and 5.76 per cent, respectively. The generation survival value was 0.47. The

positive value of trend index (1.278) indicated that the mortality factors operating during second generation were not effective in causing decline in the pest population in next generation.

Table 41. Key mortality factors for second generation of *A. janata* on castor during 1986-87, population/hectare

Age interval	Number alive at the begin- ning of x	Factors respon- sible for d_x	Number dying during x	d_x as a % of l_x	Sur- vival rate
x	l_x	d_x^F	d_x	100 q_x	S_x
Expected eggs	32,816	Sterility/ dead	9,441	11.39	0.36
Viable eggs	73,375				
Larval instars:					
Early instars (N_1)	73,375	<i>M. maculi-</i> <i>pennis</i>	32,375	44.12	0.50
(I - III)		Unknown causes	4,125	5.62	
Late instars (IV - V)	36,875	Unknown causes	2,125	5.76	0.94
Pupae	34,750	Unknown causes	125	0.36	0.99
Moths	34,625	Sex 50% females			1.00
Females x 2 (N_3)	34,625	Reproducing females	17,312		
Actual number of younger lar- vae in next generation (N_2)	93,833				
Trend index		$= N_2/N_1$	1.278		
Generation survival (SG)		$= N_3/N_1$	0.47		

Table 42 and Fig. 5 showed the budget values for second generation. The maximum contribution $k = 0.2988$ was towards the late instar larvae, the natural enemy and unknown causes being the mortality agents. The total of k 's for all stages of pest remained $K = 0.6798$. After completion of second generation, 17,312 females contributed towards multiplication of pest population in next generation.

Table 42. Budget of *A. janata* during second generation 1986-87 (35 to 39 meteorological week)

Age interval	Number/ha	Log number/ha	k 's
Expected eggs	82,816	4.9191	—
Viable eggs	73,375	4.8655	0.0526
Actual early instar larvae after mortality due to parasite and unknown causes	73,375	4.8655	0.0000
Late instar after mortality due to unknown causes	36,875	4.5667	0.2988
Pupae after mortality due to unknown causes	34,750	4.5409	0.0258
Moths	34,625	4.5393	0.0016
Reproducing females	17,312	4.2383	0.3010
			$K = 0.6798$

The results obtained on the key mortality factors for third generation (40 to 44 meteorological week) are summarised in Table 43. It is evident from Table 43 that there was 10.49 per cent mortality of eggs because of sterility. The parasite, M. maculipennis parasitized the larvae to the extent of 61.46 per cent in early instars. The mortality due to unknown causes in early and late instar group was 4.08 and 9.79 per cent, respectively. The mortality in the pupal stage because of unknown causes was 2.29 per cent. The generation survival value remained 0.30. The negative trend index value (0.159) indicated the effectiveness of parasite in keeping down the pest population in succeeding generation.

The budget values for third generation are summarized in Table 44 and Fig. 5 which reveals that the highest contribution towards generation mortality was of the early instar larvae, the major mortality agent being parasited. The 'k' value for this stage was 0.4753. The sum of k's for all the life stages of pest remained $K = 0.8793$.

Table 45 shows the details of key mortality factors operated in fourth generation (45 to 48 meteorological week). The egg mortality caused due to sterility was 13.09 per cent. The population of M. maculipennis parasite reached to the peak of 65.55 per cent. The mortality due to unknown causes in early and late instar was 4.45 and 3.71 per cent, respectively. The pupal mortality was 7.76 per cent. The mortality in all the

life stages owing to unknown causes was 15.92 per cent. The generation survival value was 0.26. The pest population was totally ecased hence, the trend index value remained nil.

Table 43. Key mortality factors for third generation of *A. janata* on castor during 1986-87, population/hectare

Age interval	Number alive at the beginning of x	Factors responsible for d_x	Number dying during x	d_x as a % of l_x	Survival value
x	l_x	$d_x F$	d_x	100 q_x	S_x
Expected eggs	1,04,841	Sterility/dead	11,008	10.49	0.89
Viable eggs	93,833				
Larval instars:					
Early instars (N_1) (I - III)	93,833	<i>M. maculipennis</i>	57,666	61.46	0.34
		Unknown causes	3,833	4.08	
Late instars (IV - V)	32,334	Unknown causes	3,167	9.79	0.90
Pupae	29,167	Unknown causes	667	2.29	0.99
Moths	28,500	Sex 50% females			1.00
Females x 2 (N_3)		Reproducing females	14,250		
Actual number of younger larvae in next generation (N_2)			15,000		
Trend index		$= N_2/N_1$		0.159	
Generation survival (SG)		$= N_3/N_1$		0.30	

Table 44. Budget of *A. janata* during third generation, 1986-87 (40 to 44 meteorological week)

Age interval	Number/ha	Log number/ha	k's
Expected eggs	1,04,841	5.0205	—
Viable eggs	93,833	4.9723	0.0482
Early instar larvae after mortality due to parasite and unknown causes	93,833	4.97 ²³	0.0000
Late instar after mortality due to unknown causes	32,334	4.5096	0.4753
Pupae after mortality due to unknown causes	29,167	4.4648	0.0448
Moths	28,500	4.4548	0.0100
Reproducing females	14,250	4.1538	0.0010
			K = 0.8793

Table 45. Key mortality factors for fourth generation of *A. janata* on castor during 1986-87, population/hectare

Age interval	Number alive at the begin- ning of x	Factors respon- sible for d_x	Number dying during x	d_x as a % of l_x	Sur- vival rate
x	l_x	d_x^F	d_x	100 q_x	S_x
Expected eggs	17,441	Sterility/ dead	2,441	13.99	0.86
Viable eggs	15,000				
Larval instars:					
Early instars (N_1)	15,000	<u>M. maculi-</u> <u>pennis</u>	9,833	65.55	0.30
(I - III)		Unknown causes	667	4.45	
Late instars (IV - V)	4,500	Unknown causes	167	3.71	0.98
Pupae	4,333	Unknown causes	333	7.76	0.92
Moths	4,000	Sex 50% females			1.00
Females x 2 (N_3)	4,000	Reproducing females		2,000	
Actual number of younger larvae in next generation (N_2)	N_{11}				
Trend index	=	N_2/N_1		N_{11}	
Generation survival (SG)	=	N_3/N_1		0.26	

Table 46 and Fig. 5 indicates the budget of fourth generation in which the mortality factors was in larval stage, the 'k' value for this stage being highest (0.5228). The next important mortality factor was in the pupal stage (0.0347). The value for total K remained 0.9405 for all the life stages.

Table 46. Budget of *A. janata* during fourth generation, 1986-87 (45 to 48 meteorological week)

Age interval	Number/ha	Log number/ha	k's
Expected eggs	17,441	4.2415	—
Viable eggs	15,000	4.1760	0.0655
Early instar larve after mortality due to parasite and unknown causes	15,000	4.1760	0.0000
Late instars after mortality due to unknown causes	4,500	3.6532	0.5228
Pupae after mortality due to unknown causes	4,333	3.6367	0.0165
Moths	4,000	3.6020	0.0347
Reproducing females	2,000	3.3010	0.3010
			K = 0.9405

V. DISCUSSION

V. DISCUSSION

Castor semilooper, Achaea janata Linnaeus is one of the important pests of castor crop in many states of India. Besides castor, it feeds on wide range of alternate host plants viz., pomegranate, ber, rose, dudhi, Bauhinia and fig. The adults are fruit suckers mainly on ber, grape, mango, guava, citrus and other ripening fruits. The food plants play a vital role in the survival and reproductive potential of insects. Relatively less information is available on the bio-eco logical studies of this pest on different hosts. Literature on life fecundity tables of A.janata on different hosts in laboratory conditions are scanty available.

The results obtained in the present investigations 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 Field life-tables and key mortality factors

5.1 Biology

The mean egg duration on all the tested plant was 2.0 days. Khan (1946) stated the egg stage lasted

for 2 to 3 days and it ranged from 3 to 5 days on castor (Pandey et al., 1967). Grundwalt (1930) reported 2 to 3 days incubation period while 3 days on castor leaves in laboratory (Snee, 1962). Byale and Bilapate (1987) reported 2.02 days egg period of Achaea while the same was 2 days on castor leaves (Bilapate, 1987).

The mean per cent of larvae of A. janata pupated was 94, 56, 80 and 55 per cent on castor, pomegranate, dudhi and rose, respectively. The mean larval duration was 11.71 on castor, 24.77 on pomegranate, 18.32 on dudhi and 24.31 days on rose. On the basis of larval duration, the preference of food plants could be arranged as castor, dudhi, rose and pomegranate.

The mean pre-pupal duration was more or less 2 days on all the host plants tested. The mean pupal duration on castor, pomegranate, dudhi and rose was 8.93, 10.32, 9.72 and 12.28 days, respectively. The order of suitability of host plants based on pupal duration was castor, dudhi, pomegranate and rose.

The mean per cent adult emergence was 94, 54, 76 and 51 per cent on castor, pomegranate, dudhi and rose, respectively. The pupal measurements were made for its length, width and weight when larvae reared on different hosts. The mean pupal length was ranged from 20.00 to 21.49 mm on rose and castor leaves. The mean

pupal width was 7.13, 6.73, 6.90 and 6.17 mm when reared on castor, pomegranate, dudhi and rose, respectively. The pupae reared on different hosts were weighed accordingly and the mean pupal weight was 670, 580, 560 and 470 mg on castor, pomegranate, dudhi and rose, respectively. It was also observed that pupae reared on castor measured greater in length and width as well as weighed heavier than other host plants tested. On the basis of pupal weight, the host plants could be arranged in descending order as castor, pomegranate, dudhi and rose.

Mean pre-oviposition period was 5 days on pomegranate, rose and it was highest i.e. 7 days on dudhi. The mean oviposition period was 8.02 on castor, 7.12 on pomegranate, 7.19 on dudhi and 6.68 days on rose, respectively. The mean fecundity was 636.0 on castor, 541 on pomegranate, 335.6 on dudhi and 389.4 eggs on rose, respectively. On the basis of fecundity, it seems that castor is more preferred host plant under laboratory conditions.

The mean life cycle was 24.48 on castor, 32.09 on dudhi, 39.33 on pomegranate and 40.38 days on rose. In all the host plants tested except rose females completed their life cycle comparatively earlier than males.

According to Byale and Bilapate (1987), the per cent larvae pupated and adult emergence was 96.19 and 96.04 per cent on castor.

Khan (1946) stated that the larval period lasted for 12 to 13 days on castor. The total larval period occupied from 10 to 16 days in monsoon and 15 to 31 days on castor in colder months (Srivastava and Pande, 1966). The larvae took 11 to 17 days to complete the development on castor leaves (Smea, 1962). The larval period on castor ranged from 9 to 23 days (Pandey *et al.*, 1967). The larval period lasted for 8 to 12 days on castor (Pant and Anand, 1975), Byale and Bilapate (1987), reported 12.38 and 19.23 days larval period on castor and pomegranate, respectively. According to them, larval period on pomegranate was prolonged and resulted into an additional instar i.e. sixth instar.

The findings obtained in the present investigations pertaining to larval duration on different host plants are in agreement with the above workers (Ramdev and Rao, 1979).

The pre-pupal period lasted for 1 to 2 days on castor (Srivastava and Pande, 1966). According to Pandey *et al.* (1967), the pupal period ranged from 7 to 26 days on castor. The pupal period occupied

10 to 15 days on castor leaves (Srivastava and Pande, 1966). Byale and Bilapate (1987) reported 8.30 days pupal period on castor. Similar results were obtained by earlier workers (Pandey et al., 1961; Sme, 1962; Subramania, 1920; Ismile and Salim, 1982; Srivastava and Pande, 1966; Byale and Bilapate, 1987 and Bilapate, 1987).

According to Khan (1946), the length and width of pupae ranged from 1.9 to 2.1 and 0.6 to 0.8 cm in case of male and 2.0 to 2.5 and 0.7 to 0.8 cm in the case of female, respectively. The mean length and width was 2.1, 0.63 and 2.3 and 0.7 cm for male and female, respectively (Srivastava and Pande, 1966). The results obtained in the present investigations are in conformity with these earlier workers.

According to Ismile and Salim (1982), the total life cycle was estimated to be one month. Total developmental period lasted for 28 days in monsoon (Khan, 1946). Byale and Bilapate (1987) reported 22.66 days life cycle on castor.

Pandey et al. (1967) reported 622 eggs per female when larvae were reared on castor. Srivastava and pande (1966) stated that the number of eggs laid per female varied from 90 to 300. The results obtained in the present investigations are in agreement with the

earlier worker (Pandey et al., 1967; Subramania, 1920; Grunwald, 1930 and Srivastava and Pande, 1966).

It is essential to remove the dudhi weed from the castor fields, rose garden and pomegranate orchards as this is one of the preferred host and may act as an alternate host of the Achaea. Generally the pest is observed on the roses when the sprouting of the rose bushes immediately after monsoon. Hence, it is very necessary to spray the rosary at this juncture. Similar is the case with pomegranate orchard also.

Now a days, the cultivation of pomegranate is increasing in the Maharashtra State and it is likely that this insect may become a major pest of pomegranate. Secondly, the sprouting of the pomegranate are generally attacked by this pest and as such initial spraying of the orchard becomes inevitable.

Further studies on sequence of attack of this pest shall be helpful in the pest management programme of castor semilooper.

5.2 Biometrical studies

Biometrical studies were made by measuring head capsule width of larvae of different instars on castor, pomegranate, dudhi and rose under laboratory conditions. According to Dyar (1890), the width of

head capsule of lepidopterous larva is more or less constant for any instar of a given species. Also the successive larval instars of a given species show more or less regular geometrical progression in the growth of head capsules. He also described that the growth ratio of the mean head capsule width of each instar and that of the preceeding 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 castor, pomegranate, dudhi and rose passed through five instars. The head capsule width of larvae averaged 0.404, 0.671, 1.243, 2.085 and 3.639 mm on castor, 0.379, 0.660, 0.986, 1.942 and 3.523 mm on pomegranate, 0.334, 0.686, 1.171, 1.664 and 3.563 mm on dudhi and 0.275, 0.581, 0.928, 1.875 and 3.462 mm on rose for I, II, III, IV and V instar, respectively.

Comparatively the calculated values of respective instars on castor, pomegranate, dudhi and rose leaves were very close to the observed values in all the cases.

When the log of head capsule width were plotted in relation to different instars of *A. janata* when reared on castor, pomegranate, dudhi and rose leaves, a definite geometrical relationship was observed for all the instars on tested host plants as derived by Dyar (1890). Thus, the head capsule width data supported the

Dyar's hypothesis indicating that the five larval instars observed in A. janata in the present studies are fairly constant on castor, pomegranate, dudhi and rose leaves.

The larvae of A. janata passed through five larval instars when reared on castor, pomegranate, dudhi and rose leaves. The instar durations were 2.32, 2.43, 2.93, 2.98 and 4.97 days on castor; 2.77, 2.90, 4.24, 5.54 and 5.92 days on pomegranate; 1.91, 3.10, 3.84, 3.47 and 7.45 days on dudhi; 3.43, 4.30, 4.69, 5.06 and 7.13 days on rose for I, II, III, IV and V instars, respectively. Comparatively the durations of all the instars were shorter when larvae reared on castor leaves except first instar. On the basis of instar durations, castor appeared to be the most preferred host plant for A. janata regarding in laboratory.

Srivastava and Pande (1966) reported five larval instars of A. janata on castor. Khan (1946) reported four larval instars while Pandey et al. (1967) reported five larval instars on castor leaves. Byale and Bilapate (1987) reported five larval instars on castor, while six larval instars on pomegranate. According to Srivastava and Pande (1966), the range of duration within instar was 2, 1 to 3, 2 to 3, 2 to 5 and 4 to 6 days for I, II, III, IV and V instar, respectively. According to Khan (1946), the first three instars were of equal duration (2 days) and the last instar i.e. IV took longer duration (5 to 7 days) on castor leaves.

According to Byale and Bilapate (1987), the instar duration were 1.54(I), 1.39(II), 1.60(III), 1.55(IV) and 4.40 days (V) on castor, while 2.40(I), 2.15(II), 2.14(III), 2.37(IV), 3.37(V) and 6.80 days (VI) on pomegranate.

The results in the present investigation in relation to the number of instars and instar durations of *A. janata* on castor leaves are in agreement with the earlier workers (Srivastava and Pande, 1966; Pandey *et al.*, 1967 and Byale and Bilapate, 1987). However, four larval instars were reported by Khan (1946) on castor and Byale and Bilapate (1987) recorded six larval instars on pomegranate which does not confirm with the present findings.

Biometrical studies have indicated that the castor is a preferred feed for *A. janata* on the basis of the weight gained by the pupae. Hence it is likely that the fecundity and rate of survival is more in castor. This situation will lead to the increasing population of the pest. Therefore, it becomes obligatory to remove stray castor plants near by the rosary as well as pomegranate orchards.

5.3 Life-fecundity tables

Life-tables can be used to make qualitative and quantitative evaluation of different host plants.

The type of life-tables developed by Birch (1948) can be used to obtain growth statistics and that can be used for both qualitative evaluation and rearing procedures and to estimate the projected potential increase in insect reared on different hosts. The innate capacity of increase has not been quantified for many insects (Wellik and Pedigo, 1973). In the present investigations, the projected potential rate of increase of *A. janata* on castor, pomegranate, dudhi and rose leaves was computed by following the method described by earlier workers (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 net reproductive rate (R_0) of *A. janata* was 325.94 on castor, 150.25 on pomegranate, 151.84 on dudhi and 101.98 females per female per generation on rose at the end of each generation. In all the host plants tested, *A. janata* has distinctly similar female birth patterns, the value of ' m_x ' rises gradually and attain a peak to be followed by a gradual decrease. Thus, it seems that from the point of view of pest multiplication, castor proved to be nutritionally the most superior host plant.

According to Byale and Bilapate (1987), the net reproductive rate (R_0) was 467.57 females per female per generation on castor leaves. The net reproductive rate (R_0) representing the total female birth was 577.49 (Kashiya 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 generation under laboratory conditions (Bilapate, 1987).

In general, the values of net reproductive rates worked out by earlier workers on castor leaves are little higher than those observed in the present investigation. The differences might have attributed because of effects of meteorological parameter during rearing.

The mean length of generation time (T) differed considerably on different hosts. It was maximum (51.14 days) on pomegranate and minimum (38.83 days) on castor. The innate capacity for increase in number (r_m) ranged between 0.09 to 0.14. On the basis of ' r_m ' values, the descending order of food plants for A. janata was castor (0.14), dudhi (0.10), pomegranate and rose (0.09). The finite rate of increase in number $_{\lambda}$ was 1.16, 1.11, 1.10 and 1.09 females per female per day on castor, dudhi, pomegranate and rose, respectively.

The age-distribution patterns more or less resemble each other in all the hosts tested. The distribution of the egg stage in the stable age-distribution was around 30 per cent except castor wherein it was

36.48 per cent. In general, the contribution of larval stage to stable age-distribution was around 65 per cent while, it was minimum 57.14 per cent on castor.

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 generations 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.

Indeed, it is evident that on the basis of net reproductive rates (R_0), innate capacity for increase in numbers (r_m) and mean generation time (T), castor occupied first position followed by dudhi, pomegranate and rose.

The life-tables giving the statistics on the (r_m) of particular species provide insight into characteristics life patterns of different species (Birch, 1948). The application of these statistics are as diverse as the insects for which the life-tables are developed. From the point of view of pest multiplication, castor with high ' r_m ' value would be the most suitable. This aspect is very well emphasized when reference is made to net reproductive rate values. A. janata would multiply 325.94 times per generation on castor while the corresponding increase in rose leaves will be as 101.98 times i.e. the population would increase by 3-fold on castor.

Several authors stated that there is a range of innate capacity for individuals of a population (De witt, 1954). Probably, the detailed life-tables of *A. janata* on castor, pomegranate, dudhi and rose plants have been worked out for the first time in the present investigation, except Byale and Bilapate (1987); Bilapate (1987) and Koshiya et al. (1986) prepared the life-tables of *A. janata* on castor host alone.

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 females 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 tune 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 (1986), the mean duration of a generation (T) was 42.44 days. The intrinsic rate of increase (r_m) was 0.1498 with a daily finite rate of increase in number (λ) 1.26.

Similar studies on life-fecundity tables of *H. armigera* and other lepidopterous pests have been conducted by earlier workers in India (Bilapate et al.,

1977; Bilapate and Pawar, 1978; Dandapani and Balasubramanian, 1979).

An attempt was made to understand the over all order of suitability of host plants for *A. janata*, in all 15 characters including aspects on biometrical studies, biology and life-fecundity tables were considered. The host plants were arranged for each character and scored by giving four points for first position and reducing the one point for each subsequent position. The total score for each host plant was considered in arranging them in the order of suitability. The host plants were arranged in ascending order for characters like larval duration, pupal duration, life cycle, pre-oviposition, generation time (T), while for the characters like head capsule width, per cent larvae pupated, growth index, per cent adult emergence, pupal weight, oviposition fecundity, survival of immature stage (l_x), net reproductive rate (R_0) and innate capacity for increase in number (r_m) they were arranged in descending order (Appendix I).

Thus, the overall order of suitability of plants in descending order with respective total points obtained was castor (55), dudhi (40), pomegranate (32) and rose (23). It was interesting to note that the order of host plants for net reproductive rate (R_0) was very much similar to the above order.

According to Singh (1985) castor was the most suitable food plant followed by pomegranate, ber and

guava for *A. janata* in respect of larval weight, larval period and percentage pupation. The findings obtained in the present investigations are in conformity with the above workers (Byale and Bilapate, 1987; Singh, 1985).

The basic characteristics of net reproductive rate (R_0) of the pest on some of its host have been worked out in the laboratory and was observed that the (R_0) was three times more in castor, one and half times more in dudhi and pomegranate as compared to rose. This data can be very well utilized in the pest management programme to have the potentiality of the pest to multiply favourable food material is available.

5.4 Field life-tables and key mortality factors

A key factor (k-factor) is any biological or environmental condition associated with mortality that is useful in predicting a future trend in a population (Morris, 1957). Life-table is not an end itself but is merely a systematic presentation of survival and mortality in a population. One or two such tables will reveal only that high mortalities may occur at certain age interval but a sequence of tables suitably replicated in time and place should increase our understanding of the dynamics of a pest population. At the same time, it reveals the most opportune periods for management of the pest.

Deevey (1947) was the first to apply this technique to growing population in nature and Morris and Millar (1954) presented the first detailed example of life-table for natural population of spruce budworm, Choristoneura fumiferana (Clemens).

The result on key mortality factors of A. janata revealed that the pest multiplied for four regular successive generations during the monsoon season of the year 1985-86 and 1986-87. The parasitization of larvae because of a parasite, Microplitis maculipennis (Szepliget) was 1.34, 4.91, 22.02 and 43.70 per cent during first, second, third and fourth generations of the year 1985-86. Parasite preferably parasitized the larvae in (second) early instars. The population levels of the pest during different generations were assessed with the help of interpretation of trend index value (1). The trend indices of pest population during first, second, third and fourth generations was 4.506, 0.301, 1.583 and 0.0, respectively. The positive trend index value viz: 4.506 and 1.583 indicated that the mortality factors operating during first and third generations were not effective in suppressing the pest population in succeeding generations.

During the year 1986-87, the mortality of early instar larvae because of M. maculipennis parasite was to the extent of 42.12, 61.46 and 65.55 per cent during

first, second, third and fourth generations, respectively. On the basis of two years data it could be seen that the parasite M. maculipennis was consistently present in nature during crop growth. The per cent parasitization by this parasite exhibited an increasing trend in both the years and reached at its peak in the last generation. The high per cent parasitization resulted in suppressing the pest population in succeeding generations.

Khan (1946) reported five to six generations of A. janata on castor in Andhra Pradesh. Five overlapping generations have been reported by Pandey et al. (1967) on castor. According to Srivastava and Pande (1966), Achaea completed three generations in Bikaner - Barmer tract, five generations in Ajmer - Bharatpur tract of Rajasthan and usually 6 to 7 generations have been reported from Karnataka (Subramania, 1921). The present findings are in agreement with the earlier worker with little variation (Khan, 1946; Pandey et al., 1967; Srivastava and Pande, 1966).

The population dynamics of an important larval parasite, M. maculipennis was worked out for two successive years and the same is presented in Table 47 and 48 (Fig. 6 and 7). The parasite, M. maculipennis was consistently present from 37th to 45th meteorological week during 1985-86 and its population was found to be in increasing trend till the pest ceased its population in field (Table 47). Similarly, the parasite parasitized

the larvae from 35th to 43rd meteorological week during 1986-87. The highest per cent parasitization was observed in 43rd meteorological week (Table 48). In the absence of parasite in field, laboratory reared parasite population could be released by inandative method.

The second instar larvae of Achaea on castor were heavily attacked by M. maculipennis parasite in Andhra Pradesh (Khan, 1946). Cherian and Basheer (1946) observed 56.2 per cent parasitization of A. janata larvae by M. maculipennis. The larvae of A. janata were parasitised to the extent of 70-75 per cent on castor in Karnataka (Rai and Jairamaiah, 1978). Subramania (1921) reported that second generation of Achaea was heavily parasitized by three species of Braconid.

The results obtained in the present investigations in relation to per cent parasitization are in conformity with the earlier workers (Khan, 1946; Rai and Jairamaiah, 1978 and Subramania, 1921).

Subramania (1921) reported that the birds like crow and maina acted as a natural enemies of Achaea larvae in Karnataka. The partial defoliation of plants and exposure of conspicuous size of the Achaea larvae attracted the predators like house crow, maina, field crow and sparrow in Karnataka (Rai and Jairamaiah, 1978).

Taniliani (1935) stated that the birds like sparrow and common crow preyed upon the fifth instar larvae of *A. janata*, however, the predation was not enough to keep the pest under check.

During field investigations, large number of predatory birds like maina, common crow were noticed to prey on full grown larvae of *A. janata* in morning and late evening hours. However, the predatory effect of birds could not be evaluated.

Field life-tables and key mortality studies have indicated the survival of the pest in the field and population fluctuation at various stages of the crop growth as well as the number of generation on castor. As far as the castor semilooper management is concerned on castor, the pest occurred immediately after start of monsoon. During the early stage of crop, in the absence of natural enemy the pest population will multiply with rapid rate.

The life-tables and its budgets have indicated that early rains followed by a long dry spell has induced the pest to multiply and to increase the population. This situation if it occurs during the crop period of castor, it can be very easily predicted that there will be spurring in pest population density and thereby necessity of control.

Table 47. Population dynamics of parasite, *M. maculipennis* on *A. janata* in respective meteorological week, 1935-36.

Sr. No.	Met. week	No. of larvae parasitized	Per cent parasitization	Ave. Temp. °C	Ave. Humidity %	Rain-fall (mm)	Sun-shine hours
1.	31 (July)	0.0	0.0	26.60	72.0	21.2	4.9
2.	32 (Aug)	3.0	8.80	26.45	69.5	14.5	4.9
3.	33 (Aug)	1.0	3.57	26.60	72.0	53.4	3.1
4.	34 (Aug)	0.0	0.00	27.56	62.5	0.0	8.4
5.	35 (Aug)	1.0	0.33	27.85	59.0	0.0	8.5
6.	36 (Sept)	0.0	0.00	27.85	58.5	5.0	8.0
7.	37 (Sept)	19.0	7.33	27.60	63.0	10.4	2.6
8.	38 (Sept)	46.0	34.58	27.50	66.0	23.8	11.8
9.	39 (Sept)	31.0	31.63	28.70	64.5	26.6	10.4
10.	40 (Oct)	10.0	20.40	27.20	74.5	128.0	6.9
11.	41 (Oct)	22.0	56.11	25.85	70.0	0.0	7.4
12.	42 (Oct)	7.0	4.96	24.60	48.5	0.0	11.1
13.	43 (Oct)	26.0	23.00	22.10	48.5	0.0	11.3
14.	44 (Oct)	212.0	68.16	21.60	48.0	0.0	11.2
15.	45 (Nov)	19.0	48.71	23.53	52.0	0.0	10.2

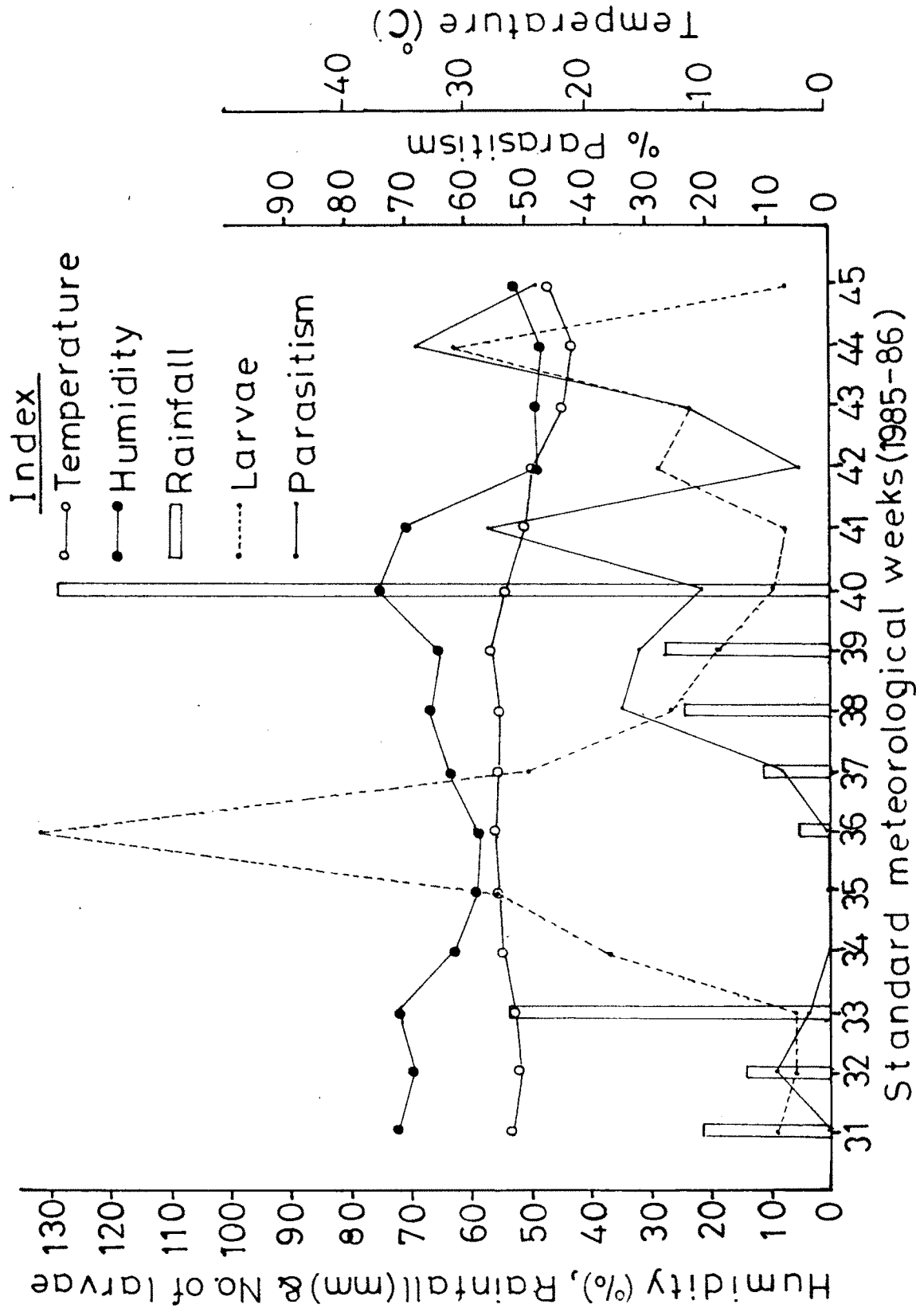


Fig 6. Population dynamics (mean of five quadrates/met. week) of A. janata and its parasite, M. maculipennis in different meteorological weeks

Table 48. Population dynamics of parasite, *M. maculipennis* on *A. janata* in respective meteorological week, 1986-87

Sr. No.	Met. week	No. of larvae parasitized	Per cent parasitization	Ave. temp. °C	Ave. Humidity %	Rain-fall (mm)	Sub-shine hours
1.	30 (July)	0.00	0.00	26.3	69.2	24.0	5.0
2.	31 (July)	0.00	0.00	28.5	68.8	15.4	9.1
3.	32 (Aug)	0.0	0.00	26.0	83.4	97.8	2.1
4.	33 (Aug)	0.0	0.00	25.4	76.5	17.8	5.1
5.	34 (Aug)	0.0	0.00	26.8	65.3	1.0	6.7
6.	35 (Aug)	27.0	19.00	27.5	61.4	13.4	10.6
7.	36 (Sept)	49.0	34.50	27.6	65.9	19.2	7.8
8.	37 (Sept)	183.0	68.79	27.7	64.6	14.6	6.2
9.	38 (Sept)	160.0	54.42	28.4	71.5	31.9	8.4
10.	39 (Sept)	150.0	77.31	28.2	62.3	6.8	10.8
11.	40 (Oct)	36.0	46.00	28.2	58.8	0.0	10.0
12.	41 (Oct)	32.0	59.25	28.1	41.3	0.0	11.2
13.	42 (Oct)	21.0	72.41	27.8	36.9	0.0	11.2
14.	43 (Oct)	6.0	35.71	24.3	40.6	0.0	11.0
15.	44 (Oct)	0.0	0.00	25.1	43.6	0.0	9.8

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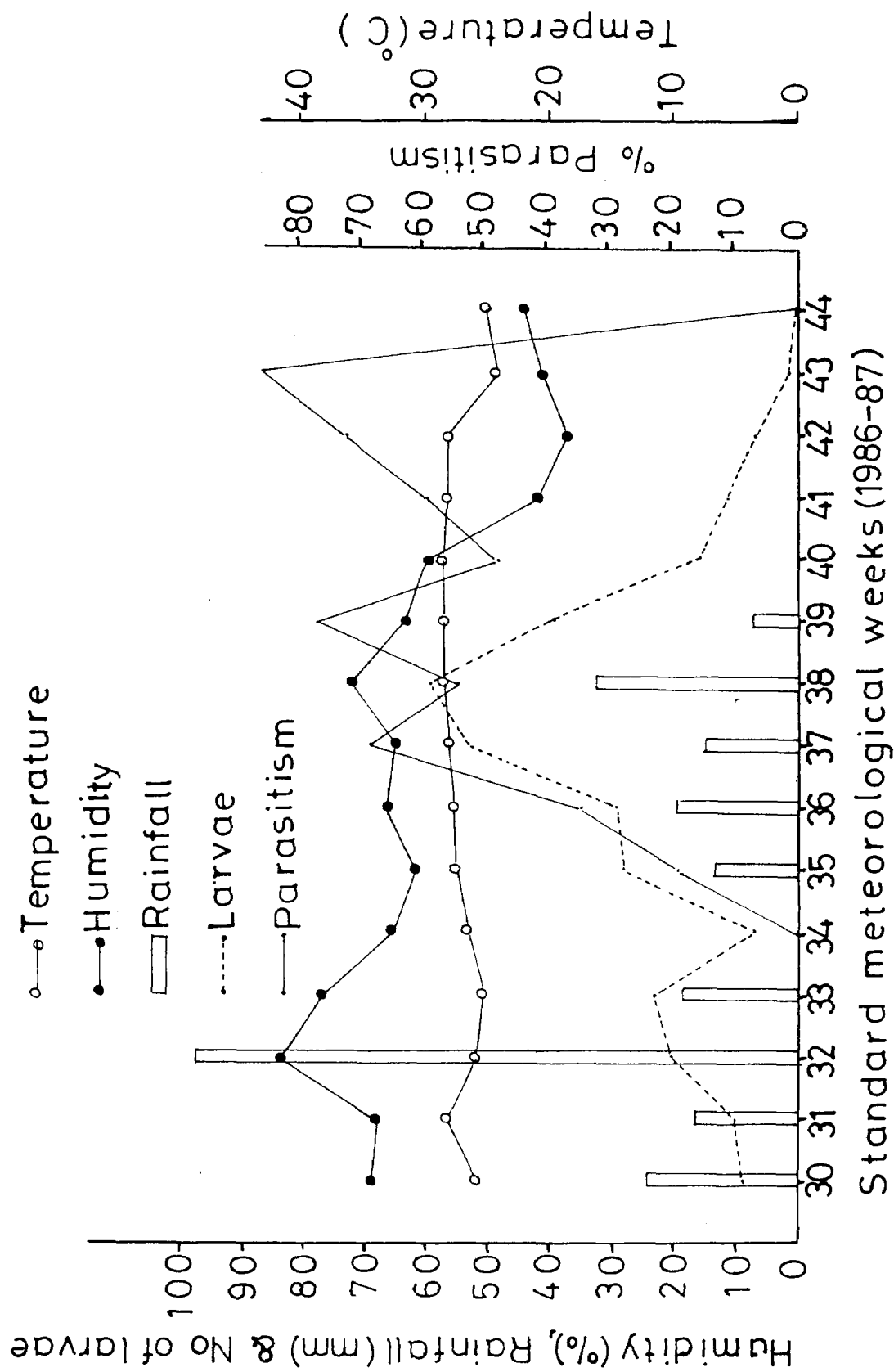


Fig 7. Population dynamics (mean of five quadrates/met.week) of Ajanata and its parasite, M. maculipennis in different meteorological weeks

It is also advocated to take chemical control measures against castor semilooper till the population of M. maculipennis built up in nature i.e. in first five weeks after sowing. Similarly second spraying if required can also be given in 36 meteorological week when the second generation of the pest has started and so also a parasite activity is in the initial stage.

From the budget studies of A. janata it has been observed that during the second and third generation population inflation occurs and it becomes inevitable to take help of the other key mortality factors such as the introduction of egg parasites like Telenomus predator and Trichogramma achaea as well as early artificial inoculation of M. maculipennis a promising larval parasite identified during the present investigations.

VI. SUMMARY AND CONCLUSIONS

VI. SUMMARY AND CONCLUSIONS

Investigations were carried out at Marathwada Agricultural University, Parbhani, Maharashtra to study the bio-ecological aspects of castor semilooper Achaea janata Linnaeus in laboratory and field. Studies on biology, biometrics and life-fecundity tables were conducted on four alternate hosts viz. castor, pomegranate, dudhi and rose. During the course of investigations the prevailing laboratory average minimum and maximum temperatures were 25°C to 30°C respectively. Field life-tables and key mortality factors were studied on castor during monsoon season of the year 1985-86 and 1986-87.

6.1 Biological studies shows that the mean larval duration was 11.71, 27.77, 18.32 and 24.31 days on castor, pomegranate, dudhi and rose, respectively. The mean per cent larvae pupated remained 94, 56, 80 and 55 per cent respectively. The growth index value was highest (8.02) on castor followed by dudhi (4.36). Pupal duration was shortest 8.93 days on castor and 10.32 days on pomegranate.

The larvae of A. janata passed through five larval instars on all the four host plants tested in laboratory. Thus, the head capsule width data supported by Dyar's hypothesis. Instar duration for five instars on all the four host plants were noted. The mean life cycle from egg to adult emergence was shortest on castor (24.48 days) followed by dudhi (32.09 days) and pomegranate (39.33 days) while it was longest (40.33 days) on rose.

Taking into consideration the above points, it is essential to remove the dudhi weed from the castor fields, rose garden and pomegranate orchards as it seems one of the preferred host during present studies and may act as an alternate host for pest.

6.2 Biometrical studies were undertaken in respect of head capsule width of larvae in different instars when reared on castor, pomegranate, dudhi and rose under laboratory. The mean observed head capsule width of A. janata larvae on castor was 0.40, 0.67, 1.24, 2.08 and 3.63 mm for I, II, III, IV and V instars, respectively. The head capsule width was 0.37, 0.66, 0.98, 1.94 and 3.52 mm for five larval instars on pomegranate. The head capsule width measured 0.33, 0.68, 1.17, 1.66 and 3.56 mm for five instars on dudhi while it was 0.27, 0.58, 0.92, 1.87 and 3.46 mm on rose.

The pupal measurements were taken for its length, width and weight when larvae reared on different hosts. The mean pupal length was 21.49, 20.28, 20.72 and 20.00 mm on castor, pomegranate, dudhi and rose, respectively. The mean pupal width was 7.18, 6.73, 6.90 and 6.17 mm respectively. The pupal weight was 670, 580, 560 and 470 mg on castor, pomegranate, dudhi and rose, respectively.

Biometrical studies have indicated that the castor is a preferred food for A. janata on the basis of

weight gained by the pupae. Hence, it is likely that the fecundity and rate of survival is more in castor. This situation will lead to the increasing population of the pest.

6.3 Life-fecundity studies shows that the mean pre-oviposition period ranged from 5 to 7 days and fecundity was highest i.e. 636 eggs per female on castor followed by 541.6 on pomegranate, 389.4 on rose and 385.6 on dudhi. The growth parameters viz. survival of immature stages, contribution towards the female birth, and net reproductive rate gave different values when reared on different host plants.

The net reproductive rate (R_0) was 325.94 on castor, 150.25 on pomegranate, 151.84 on dudhi and 101.98 females per female per generation on rose. The innate capacity for increase in number (r_m) was 0.1490 on castor, 0.0980 on pomegranate, 0.1090 on dudhi and 0.0926 on rose, respectively. The daily finite rate of increase in numbers (λ) remained 1.16, 1.11, 1.10 and 1.09 females per female per day on castor, dudhi, pomegranate and rose respectively. On reaching stable age-distribution there was maximum contribution (99 per cent) by immature stages in all the host plants tested. Laboratory life-tables studies will give a clue about the population build up behaviour of *A. janata*.

6.4 The field studies on life-tables, key mortality factors and preparation of budget have indicated the survival of the pest in field and population fluctuation at various stages of the crop growth as well as the number of generations on castor. The A. janata passed through four regular over-lapping generations on castor during two successive years. The parasitization of A. janata larvae in early instars (I-III instar) by parasite Microplitis maculipennis (Sziesligetis) was 1.34, 4.41, 22.02 and 43.70 per cent in first, second, third and fourth generation respectively during 1985-86. Similarly, the larval parasitization by M. maculipennis during second, third and fourth generation was 44.12, 61.46 and 65.55 per cent, respectively in the second year i.e. 1986-87 of the experiment.

The predatory birds like maina and crow were observed to prey on full grown larvae in the field. The mortality of larvae and pupae was observed because of unknown reasons.

The field studies have indicated that early rains followed by long dry spell induces the pest to multiply and to increase the population. This situation if it occurs during the crop growth period of castor it can be very easily predicted that there will be a spurt in pest population density and thereby necessitating of pest control.

Field studies on castor indicates that during the early stage of crop in the absence of natural enemy the pest population will multiply with rapid rate. Hence it is advocated to take chemical control measures against this pest till the population of M. maculipennis build up in nature i.e. during first five weeks after sowing. Similarly, second spraying if required can also be given after fifteen days.

From the budget studies of A. janata it has been observed that during the second and third generation, population inflation occurs and it becomes inevitable to take help of the key mortality factor such as the introduction of egg parasites like Telenomus predator and Trichogramma achaeae as well as the early artificial inoculation of Microplitis maculipennis a promising larval parasite identified during the present investigations.

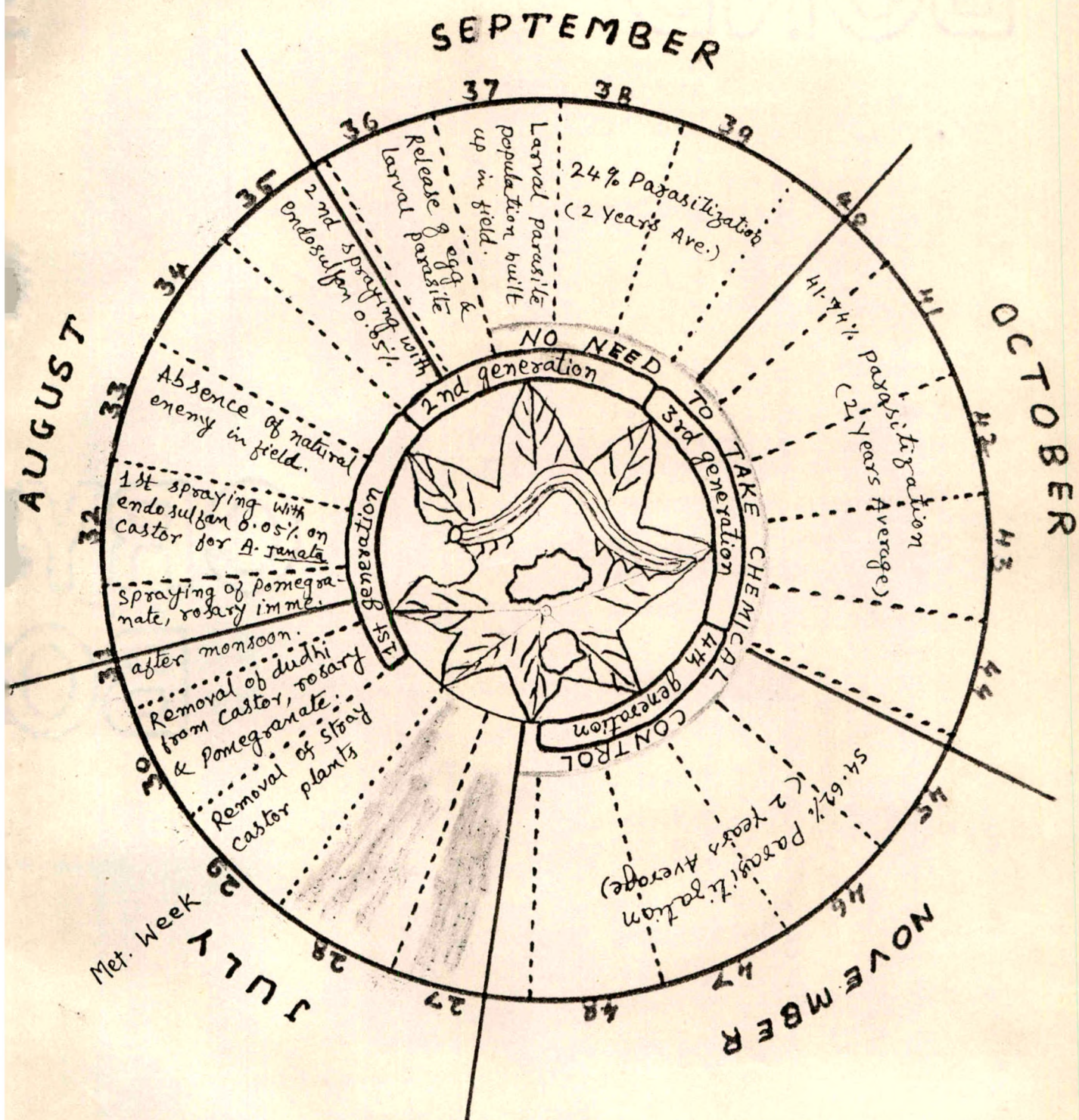
From the month of September onwards, there is no need to have control measures against A. janata, as parasite population will reach to its peak and parasitise the larvae to the greater extent and will present in nature till the pest ceases in the field. Thus, M. maculipennis could be considered as important parasite in integrated pest management programme of A. janata on castor.

On the basis of present investigations, following conclusions can be drawn.

1. Population studies have indicated that early rains followed by a long dry spell induced the pest to multiply at a faster rate.
2. It is very necessary that the stray castor plants near by the pomegranate orchards as well as rosary to check the pest population.
3. It is essential to remove dudhi weed, an alternative host of the pest from castor fields, rose garden and pomegranate orchard.
4. It is always better to spray the rosary immediately after monsoon to save the sprouting plants from the attack of the pest.
5. The cultivation of pomegranate in Maharashtra State is increasing and it is likely that this insect may become a major pest of this crop. Hence, it is advised to spray the crop after monsoon showers.
6. Field studies on castor indicated that the pest population increases at a faster rate during first five weeks in the absence of parasite, M. maculipennis hence, it is necessary to spray

the crop once or twice as per requirement at an interval of 15 days.

7. It has been observed that during the II and III generation population inflation of pest occurs hence, it will be better to introduce key mortality factors like egg parasite *Tele. nana* predator, *Trichogramma achaea* and inoculative release of *M. maculipennis*.
8. From the month of September, there is no need of control of *A. janata* as the parasite population *M. maculipennis* reaches its peak.



STRATEGY FOR MANAGEMET OF
CASTOR SEMILOOPER *Achaea janata* L.

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- *Original not seen.

APPENDIX

Appendix-I. Relative order of different parameters for growth and development of *A. janata* on four host plants

Characters	Hosts			
	1	2	3	4
Head capsule width	Rose	Dudhi	Pomegranate	Castor
Larval duration	Castor	Dudhi	Pomegranate	Rose
Per cent larvae pupated	Castor	Dudhi	Pomegranate	Rose
Growth index	Castor	Dudhi	Pomegranate	Rose
Pupal duration	Castor	Dudhi	Pomegranate	Rose
Per cent adult emergence	Castor	Dudhi	Pomegranate	Rose
Pupal weight	Castor	Pomegranate	Dudhi	Rose
Life cycle	Castor	Dudhi	Pomegranate	Rose
Pre-oviposition	Rose	Pomegranate	Castor	Dudhi
Oviposition	Castor	Dudhi	Pomegranate	Rose
Fecundity	Castor	Pomegranate	Rose	Dudhi
l_x	Castor	Dudhi	Pomegranate	Rose
R_o	Castor	Dudhi	Pomegranate	Rose
r_m	Castor	Dudhi	Pomegranate	Rose
T	Castor	Dudhi	Rose	Pomegranate