BIOLOGY OF *Mythimna separata* (WALKER) (LEPIDOPTERA : NOCTUIDAE) ON RICE CROP

Thesis

Submitted to the Punjab Agricultural University
in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE
in
ENTOMOLOGY
(Minor Subject : Plant Pathology)

By

Hardev Singh
(L-2002-A-19-M)

Department of Entomology
College of Agriculture
PUNJAB AGRICULTURAL UNIVERSITY
LUDHIANA - 141 004
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Gift

CERTIFICATE I

This is to certify that the thesis entitled **"Biology c *Mythimna separata* (Walker) (Lepidoptera : Noctuidae) on Ric Crop"** submitted for the degree of **M.Sc.** in the subject c **Entomology** (Minor Subject: Plant Pathology) to the Punja Agricultural University, Ludhiana, is a bonafide research wor carried out by **Hardev Singh (L-2002-A-19-M)** under my supervisio and that no part of this thesis has been submitted for any othe degree.

The assistance and help received during the course of investigation have been fully acknowledged.

Thesis

Jaswant Singh
11-1-05

Major Advisor
(Dr. Jaswant Singh)
Senior Entomologist (Rice)
Department of Plant Breeding,
Genetics and Biotechnology
Punjab Agricultural University
Ludhiana – 141 004

17105

CERTIFICATE II

This is to certify that the thesis entitled, **"Biology of *Mythimna separata* (Walker) (Lepidoptera : Noctuidae) on Rice Crop"** submitted by **Hardev Singh (L-2002-A-19-M)** to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of **M.Sc.** in the subject of **Entomology** (Minor Subject: Plant Pathology) has been approved by the Student's Advisory Committee along with Head of the Department after an oral examination on the same.

1.3.05

Head of the Department
(Dr. G.S. Deol)

Jaswant Singh
28-2-05

Major Advisor
(Dr. Jaswant Singh)

11/3

Dean, Post-Graduate Studies
(Dr. Darshan Singh)

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Dated : 11.1.05

(Hardev Singh)

Department of Entomology
College of Agriculture
Punjab Agricultural University
Ludhiana - 141004

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ABSTRACT

Biology of *Mythimna separata* was studied on rice during kharif 2004 at Punjab Agricultural University, Ludhiana. Number of eggs (size 0.60 ± 0.04 mm) per cluster varied from 9 to 57 ; fecundity being 62 – 235. Oviposition occurred during night, peak period being 02:00- 04:00 hrs. Egg stage lasted for 5-10 days. Larvae passed through six instars. Body length and breadth of I, II, III, IV, V and VI instars measured 3.80 ± 0.04 and 0.34 ± 0.03; 6.88 ± 0.18 and 1.12 ± 0.12; 16.90 ± 0.31 and 2.17 ± 0.12; 25.02 ± 0.31 and 2.87 ± 0.18; 34.32 ± 0.57 and 3.26 ± 0.12 and 43.14 ± 0.48 and 4.12 ± 0.13 mm, respectively. The length and breadh of the head capsule of different instars was 0.29 ± 0.03 and 0.48 ± 0.04, 0.76 ± 0.08 and 1.27 ± 0.05, 1.46 ± 0.19 and 1.96 ± 0.12, 1.82 ± 0.26 and 2.33 ± 0.17, 2.23 ± 0.28 and 2.72 ± 0.13 and 2.61 ± 0.30 and 3.37 ± 0.20 mm ; duration of respective instars was 2.54 ± 0.38, 3.26 ± 0.47, 3.58 ± 0.51, 3.99 ± 0.62, 4.21 ± 0.71 and 4.80 ± 0.75 days. Larval period was maximum (24.65 ± 0.57 days) during September and minimum (19.85 ± 0.26 days) during June-July. Pupation mostly (76.50%) took place inside the clumps of the rice plants ; it also occurred in soil (23.50%). Pupal period was 7.81 ± 1.38 days in male and 8.61 ± 1.22 days in female. Mating usually occurred during night (peak period between 22:00 - 02:00 hours). Pre-oviposition, oviposition and post-oviposition periods were 1.95 ± 0.53, 3.13 ± 0.39 and 2.57 ± 0.27 days, respectively. Longevity of adults averaged 5.46 ± 0.51 (male) and 7.53 ± 0.35 days (female). Life cycle was completed in 38.68 ± 2.08 days. *M. separata* passed through four generations during rice season. Berseem (*Trifolium alexanderinum* Linn.) was recorded to be a new host for *M.separata*. *Apanteles ruficrus, Calosoma indicum,* Nucleopolyhedrosis virus (NPV) and White muscardine fungus were observed to infect the larvae of the insect.

Key words : Biology, *Mythimna separata* (Walker), Rice ear-cutting caterpillar, Rice, Host range, Seasonal history.

Jaswant Singh 11-7-05

(Signature of Major Advisor)

Hardev Singh

(Signature of Student)

CONTENTS

CHAPTER I

INTRODUCTION

"Rice means life" (the FAO theme of International Year of Rice 2004). Rice (*Oryza sativa* L.) is the world's most important food crop feeding more than half of the mankind. It is the staple food of about two-third population of India. In India, rice was cultivated on 44.6 million hactares with a total production of 93.08 million tonnes during 2001-02 (Anonymous 2003).

Punjab is non-traditional, but has now become one of the most important rice growing region of the country, as it contributes more than 40 per cent of rice to the national pool. It is a major *kharif* crop of Punjab where it was grown on 2.53 million hectares with a total production of 8.88 million tonnes during 2002-03 (Anonymous 2003).

Rice is a crop of warm, humid environment conducive to survival and proliferation of many insect pests. All parts of the rice plant from root to tip (vegetative and reproductive) and all the stages of crop from germination to harvest are damaged by one or the other pest. In the Punjab about a dozen insect pests namely, stemborers [*Scirpophaga incertulus* (Walker), *S. innotata* (Walker) *Sesamia inferens* (Walker)], whitebacked planthopper *Sogatella furcifera* (Horvath), brown planthopper *Nilaparvata lugens*, (Stal), leaffolder *Cnaphalocrocis medinalis* (Guenee), rice hispa *Dicladispa armigera* (Olivier), rootweevil

Echinocnemus oryzae (Marshall), thrips *Baliothrips biformis* (Bagnall), grasshoppers *Hieroglyphus banian* (Fabrisius), *oxya* spp. and rice ear-cutting caterpillar (*Mythimna separata* Walker) are recorded as serious pests.

The rice ear-cutting caterpillar *Mythimna separata* (Walker) also known as 'army worm' is a polyphagous pest and has several host plants (Helson 1970, Tripathi *et al* 1982b, Singh and Chaudhary 1988, Deol and Singh 1991). Numerous cultivated crops including rice, maize, wheat, sorghum, arhar, bajra, oats, johnson grass are attacked by this pest (Singh and Chaudhary 1988). It is a serious pest of cereals in Asia and Australia and has been recorded to cause 16 serious outbreaks on various crops in India (Sharma and Davies 1983). In severe outbreaks, the entire rice plant may be consumed (Grist and Lever 1979). According to Alam (1960) 100 per cent damage occurred to eared Aman rice in East Pakistan (Now Bangladesh). In that country in 1955, there was damage to 50,000 acres with a loss of Rs 7.5 lakhs (Over £ 40,000 sterlings). In Punjab, *M. separata* was first recorded damaging earheads near maturity during October 1980 in village Buanangal, District Amritsar and the incidence was 4 per cent fallen panicles (Singh 1988). Since the damage due to this pest is noticed suddenly when the crop is nearing maturity , it is considered as a serious pest of rice in Punjab.

Some work on the biology of this pest has been carried out in some parts of India *viz.* Madhya Pradesh (Patel *et al* 1981), Tripura

(Pandey and Ganguli 1985), Haryana (Singh 1987), Maharashtra (Bhole *et al* 1989) and eastern Uttar Pradesh (Singh and Rai 1989) on rice, and on wheat in Punjab (Bindra and Singh 1973, Deol and Singh 1991). However, no such systematic studies of this insect on rice had been conducted in the Punjab state. Keeping in view its economical importance, the biology of rice ear-cutting caterpillar, *M. separata* (Walker) on rice crop was studied.

The present work, therefore was conducted with the following objectives:

1. To study the detailed biological parameters of *Mythimna separata* on rice.
2. To study the host range, seasonal abundance and natural enemies of this pest.

CHAPTER II

REVIEW OF LITERATURE

The armyworm *M. separata* is a pest of graminaceous crops all over the world (Atwal and Dhaliwal 1999). In India too, it has been reported as a serious pest of many cereal crops particularly infesting paddy, maize, sorghum and sugarcane crops (Butani 1955, Bindra and Rathore 1966, Tripathi *et al* 1982b, Singh and Chaudhary 1988, Deol and Singh 1991). Outbreak of *M. separata* has been reported from Australia (Farrow and McDonald 1967), Bangladesh (Alam 1967, Dean 1979, Philippines (Cadapan and Sanchez 1972), Pakistan (Dar *et al* 1979) and Japan (Fuse and Saito 1988, Kanda and Naito 1989, Ishioka *et al* 2002). Outbreak of this pest mainly from rice in India have also been reported by Sinha *et al* (1979) and Jamadar *et al* (1980) in Bihar, Chaudhary and Singh (1980) in Haryana, Barwal (1983) and Barwal *et al* (1994) in Manipur, Moray *et al* (1983) in Maharashtra, Rajagopal and Musthak (1992) and Kumar (2003) in Karnataka.

Distribution

Mythimna. separata is one of the most serious pests of cereals in Asia and Australia and has been recorded from 27 countries, territories and islands ranging from the humid tropics to the temperate regions (Sharma and Davies 1983). Grist and Lever (1969) reported the pest in the Russian Far East, Sakhalin, Afghanistan, India, Manchuria,

Pakistan, Ceylon, Thailand, Burma, Sabah, Java, Celebes, Cambodia, Taiwan, Vietnam, Philippines, Japan, Korea, China, West Irian, New Guinea, Papua, Fiji, Norfolk Island, Queensland, New South Wales, Western Samoa and New Zealand. Dale (1994) reported it from Southern Canada, Southern Europe, Central and some South American countries. Distribution of this pest has also been reported from Pakistan, Sri Lanka, Burma, Thailand, Java, Celebes, Vietnam, Taiwan, Philippines, Japan, Korea, China, New Guinea and Australia (Nayar *et al* 2000). Larry (2002) reported the occurrence of *M. separata* from United States, Arizona, California and New Mexico.

In India, the occurrence of *M. separata* on rice was recorded in Punjab (Singh and Deol 1986; Saini 1987; Singh 1988), Haryana (Chaudhary and Singh 1980; Chander *et al* 2003), Rajasthan (Patel 1979), eastern Uttar Pradesh (Singh and Rai 1989), Uttar Pradesh and Orrisa (Verma *et al* 1971, Patel *et al* 1979), Madhya Pradesh (Subash *et al* 2003), Maharashtra (Bhole *et al* 1989), Karnataka (Kumar 2003) and the entire north-eastern regions including Assam, Manipur, Tripura, Meghalya and Sikkim (Barwal *et al* 1994).

Taxonomy

M. separata belongs to family Noctuidae and Order Lepidoptera (Cadapan and Sanchez 1972, Ko *et al* 2003).Eight species of armyworms are reported to attack rice in China, namely, *Mythimna separata* (Wlk), *M. loreyi* (Dup.), *Vietteania compta* (*M. compta*), *M. zeae*

(Dup.), *Spodoptera mauritia* (Boisd.), *S. depravata* (Btlr.), *Ariathisa abyssinia* (Gn.) (*S. abyssinia*) and *S. pecten* Gn. Among these *M. separata* is the most important (Wu 1982). Following synonyms of *M. separata* have been listed by (Grist and Lever 1969, Ghai *et al* 1979, Dale 1994).

- *Cirphis unipuncta* (Haworth)
- *Leucania unipuncta* (Haworth)
- *Mythimna convecta* (Walker)
- *Pseudaletia seprata* (Waker)
- *Leucania separata* (Walker)
- *Leucania convecta* (Walker)

Life cycle

Studies on life history of *M. separata* on rice have been reported from Bangladesh (Alam 1967), Philippines (Cadapan and Sanchez 1972), China (Wei 1982) and Korea Republic (Ko *et al* 2003). In India, the life history of *M. separata* on rice was studied by Patel *et al* (1981) in Madhya Pradesh, Tripathi *et al* (1982) in Uttranchal Pradesh, Bhole *et al* (1989) in Maharashtra, Singh and Rai (1989) and Pandey and Tiwari (2001) in eastern Uttar Pradesh, and Chandrakar and Shrivastava (2002) in Chhatisgarh. In Punjab, the study on life cycle was conducted on wheat by Bindra and Singh (1973), and Deol and Singh (1991). The identification characteristics, measurements and parameters of the life cycle of *M. separata* reported by various workers are presented in Tables 1, 2 and 3, respectively.

Table 1 : Identification characteristics of *M. separata*

Stage of insect	Characteristic feature	Reference(s)
Adult	Forewings are pointed at the tips, reddish grey or fawn in colour, and highly specked with black atoms. Anterior to the centre of each wing are two rather large indistinct spots, distinguished from the rest of the wing by an absence of black specks and by a clearer reddish colour. Immediately posterior to the outermost spots is a white point with an indistinctly blackish surrounding. The hindwings are translucent with blackish terminal border nervures, but with whitish nervures in the front wings. Along the outer margin, particularly of the hind wings, are many black specks, so nearly confluent as to form a limited dusky terminal band. The body is concolorous with the wings and the legs are light grey, slightly reddish, tinged and specked with black dots.	Alam (1967)
	Forewings : Brownish gray with a distinct white spot in the center pale spot	Grist & Lever (1969), Dale (1994), Larry (2002), Avasthi (2002)
	Hindwings : Pale with a brown tinge darker veins suffused with fuscous brown colour	Grist and Lever (1969), Nayar *et al* (2000), Larry (2002)
Egg	Freshly laid eggs are round, light brown and with a shining smooth egg shell	Deol and Singh (1991)
	Shining white, spherical with fine reticulations	Nayar *et al* (2000)
	Subspherical, greenish white, turning yellow	Avasthi, Grist and Lever (1969)
Larva	Head : Greyish brown Body : Dirty pale brown or dark with a median brown line and two dark brown and one white lateral stripes.	Nayar *et al* (2000)
	Head: Pale brown with green and dark mottling Body: Green to brown and have a distinctive pattern of longitudinal stripes. A dark stripe along each side and a broad stripe is found along the back. The dorsal stripe has a fine, light coloured broken line running down the center.	Larry (2002)
	Head : Brown with six ocelli on each side Body: Colour very variable from green to pinkish, four longitudinal black stripes running laterally with a white mid-dorsal stripe in the early stages, darkening later	Grist and Lever (1969)
Pupa	Shining, two long curved cremastral spines	Grist and Lever (1969)
	Colour changed from light to dark brown with advance in the age	Deol and Singh (1991)
	Dark brown in colour	Avasthi (2002)

Table 2 : Measurements of different stages of *M. separata*

Stage of insect	Measurement	Reference
Egg	0.5 mm x 0.45 mm	Grist and Lever (1969)
	0.6-0.7 mm (dia)	Pathak (1977)
	0.73 mm x 0.57 mm	Pandey and Tiwari (1998)
Larva (I instar)	1.8 mm x 0.35 mm	Pathak (1977)
Larva (full grown)	35.0 mm x 6.5 mm	Alam (1967)
	30-35 mm x 6-6.5 mm	Pathak (1977)
	35-40mm (Length)	Grist and Lever (1969) Avasthi (2002)
Pupa	17mm x 6 mm	Alam (1967)
	15-19 mm x 6 mm	Pathak (1977)
	16.76 mm x 6.48 mm	Pandey and Tiwari (1998)
	15-19 mm (length)	Avasthi (2002)
Adult	40 mm (wing expanse)	Alam (1967)
	45-50 mm (Wing expanse)	Grist and Leverl (1969)
	2-3 cm (body length)	Pathak (1977)
	3-5 cm (wing expanse)	
	21.97 mm x 9.39 mm (body length x width)	Pandey and Tiwari (1998)
	35-50 mm (wing expanse)	Avasthi (2002)
	40 mm (Wing expanse)	Larry (2002)

Table 3: Life cycle parameters of *M. separata* as reported by various workers

Stage	Parameter	Days/number	Crop	Place	Reference(s)
Egg	Fecundity (Eggs/female)	285-375	Wheat	eastern Uttar Pradesh	Singh and Rai (1989)
		92-250	Sugarcane	eastern Uttar Pradesh	Singh and Rai (1989)
		150-400	Maize	eastern Uttar Pradesh	Singh and Rai (1989)
		300-325	Rice	eastern Uttar Pradesh	Singh and Rai (1989)
		519	Rice	eastern Uttar Pradesh	Pandey and Tiwari (1998)
		232	Rice	Bangladesh	Alam (1967)
		816.6	Maize	Korea Republic	Ko *et al* (2003)
	Duration	4-5 (April) 19 (January)	Wheat	Punjab	Bindra and Singh (1973)
		4-22	Wheat	Punjab	Deol and Singh (1991)
		2.5	Rice	Uttar Pradesh	Singh *et al* (1989)
		4.8	Rice	eastern Uttar Pradesh	Pandey and Tiwari (1998)
		5-7	Rice	Madhya Pradesh	Patel *et al* (1981)
		3-18	Rice	Maharashtra	Bhole *et al* (1989)
		7-9	Rice	Bangladesh	Alam (1967)
		4-6	Rice	China	Wei (1982)
		4-13	Rice	Korea	Grist and Lever (1969)
		8	Rice	USA	Larry (2002)

Larva	Number of instars	6	Rice	Bangladesh	Alam (1967)
		6	*Cyperus rotundas*	U.P.	Singh *et al* (1989)
		6	Rice	-	Dale (1994)
		6	Rice	M.P.	Chandrakar and Shrivastava (2002)
		6	Rice	Phillipines	Cadapan and Sancheh (1972)
	Duration	13-14 (March-April 88-100 (winter)	Wheat	Punjab	Bindra and Singh (1973)
		24-28 (March) 56-69 (Jan-Feb)	Wheat	Punjab	Deol and Singh (1991)
		22-27	Rice	Madhya Pradesh	Patel *et al* (1981)
		23-74	Rice	Maharashtra	Bhole *et al* (1989)
		15.60	Rice	eastern Uttar Pradesh	Singh and Rai (1989)
		29.85 (20°C) 22.57 (30°C)	Rice	eastern Uttar Pradesh	Pandey and Tiwari (1998)
		23	Rice	India	Nayar *et al* (2000)
		20-48	Rice	Bangladesh	Alam (1967)
		20-26	Rice	Phillipines	Cadapan and Sanchez (1972)
		16.5-36.5	Rice	China	Wei (1982)
Pre-Pupa	Duration	1.7	Maize	Haryana	Singh and Chaudhary (1989)
		1.40	Maize	Uttar Pradesh	Singh and Rai (1989)
		1.50	Rice	Maharashtra	Bhole *et al* (1989)
		1.60	Rice	Uttar Pradesh	Singh and Rai (1989)

Pupa	Duration	9-13	Wheat	Punjab	Bindra and Singh (1973)
		8-32	Wheat	Punjab	Deol and Singh (1991)
		7-22	Wheat	India	Avasthi (2002)
		9-13.1	Rice	India	Tripathi *et al* (1982)
		9.05	Rice	Maharashtra	Bhole *et al* (1989)
		5.25	Rice	eastern Uttar Pradesh	Singh and Rai (1989)
		7-11	Rice	eastern Uttar Pradesh	Pandey and Tiwari (1998)
		7-29	Rice	Bangladesh	Alam (1967)
Adult	Duration	1-6	Wheat	Punjab	Bindra and Singh (1973)
		4-11	Wheat	Punjab	Deol and Singh (1991)
		4-8	Rice	Haryana	Singh (1987)
		5-7	Rice	Maharashtra	Bhole *et al* (1989)
	Male	5.8	Rice	eastern Uttar Pradesh	Singh and Rai (1989)
	Female	6.0			
	Male	3	Rice	Bangladesh	Alam (1967)
	Female	7			
		8-12.3	Rice	Korea Republic	Ko *et al* (2003)

Pre-oviposition		1-3	Rice	-	Pathak (1977)
		2.9 (30°C)	Rice	Korea republic	Ko *et al* (2003)
		4.2 (15°C)	Rice	Korea republic	Ko *et al* (2003)
Oviposition period	Duration	5	Rice	Bangladesh	Alam (1967)
		4	Rice	India	Pandey and Tiwari (1998)
Total life cycle		25-64 (31)	Wheat	India	Avasthi (2002)
		32.5	Maize	Korea Republic	Ko *et al* (2002)
		46.6	Soybean	Korea Republic	Ko *et al* (2002)
		33-45	Rice	Madhya Pradesh	Patel *et al* (1981)
		30-36	Rice	Tripura	Pande and Ganguly (1985)
	Male	22.45	Rice	Uttar Pradesh	Singh and Rai (1989)
	Female				
		50.19 (20°C) 36.83 (30°C)	Rice	Eastern Uttar Pradesh	Pandey and Tiwari (1998)
		8 weeks	Rice	East Pakistan (Now Bangladesh)	Grist and Lever (1969)
		32	Rice	Phillipines	Cadapan and Sanchez (1972)

Adults moths are nocturnal, strongly phototropic and remain quiescent during the day (Avasthy and Chaudhary 1965, Deol and Singh 1991). Mating and ovipositon were reported to occur after dark and during early evening hours (Pathak 1977). Female moth generally prefer to oviposit her eggs in tight places which conceal her eggs, like narrow space between the sheath and blade of growing grasses, rice or cut, dried straw of grass stalks which tend to fold length wise (Alam 1967). Bindra and Singh (1973) reported that the fully grown larvae were negatively phototactic and preferred relative humidities of 75-100%. The armyworm attack started from the periphery, but later on it spread to whole wheat field (Deol and Singh 1991). The caterpillars are voracious feeders, eating entire leaves and the whole plant usually during nights and migrates from one field to another field (Avasthi 2002). The full grown larvae stopped feeding and spun a loose silken cocoon 5-7 cm below the soil, in water bunds and also in wheat stubbles (Deol and Singh 1991). Pupae were found without cocoons between the tillers or in earthen cocoons in the soil near the base of the plant (Patel *et al* 1981). Rizvi and Singh (1985) also reported pupation under fallen leaves and bunds in the fields.

Number of generations

Five generations in a year have been reported from Bangladesh (Alam 1967). As higher as eight generation in China (Wei 1982) have been reported. Larry (2002) reported three generations on rice in USA.

Number of generations per year has been variously reported as three to five (Grist and Lever 1969), three to four (Dale 1994) and five (Avasthi 2002). In India, occurrence of three to four generations during rice season in Rajasthan has been reported by Patel (1979). In Punjab, four generations have been reported to be completed from October to June (Bindra and Singh 1973) and from October to mid July (Deol and Singh 1991) on wheat in the screen-house.

Seasonal History

In the Philippines, Cadapan and Sanchez (1972) reported that *M. separata* was abundant in August-September in the wet season and January-February in the dry season. In China, the pest migrates from Southern Provinces to the North-eastern provinces in early spring, returning in late summer or autumn. Rice and maize crops were attacked in September-October while wheat crop was attacked in March-April (Wu 1982).

In Jabalpur (MP), *Mythimna* larvae were found feeding on the leaves and cobs of sorghum and maize in July and August where one generation was completed on these crops. The following generation began on rice in September, the heaviest damage occurring between September and mid October (Patel 1980). In Manipur, outbreak of *M. separata* occurs in late October, following usually heavy rains between February and September (Barwal 1983). In Agartala (Tripura), the

incidence of the pest was highest during October-November (Pande and Ganguli 1985). In Maharashtra, there were two population peaks *viz.* in October and April-May (Bhole *et al* 1989). In South India, adults were generally caught in light traps 15-20 days after the initiation of the monsoon rains in the first week of June, and reached a peak in September, nearly one month after the peak in larval density. Rain , and maximum and minimum relative humidity were positively associated with moth catches in light traps, while maximum temperature, open pan evaporation, solar radiation, sunshine hours, and wind velocity showed a negative correlation with moth abundance (Sharma *et al* 2002). Singh *et al* (1987) in Haryana reported that in September, pearl millet was the most seriously damaged crop with larval populations ranging from 1-3 per plant and leaf damage was observed on maize, sugarcane and Napier grass. After pearl millet and maize were harvested, sporadic leaf damage and isolated larval populations were observed on sugarcane and Napier grass in October-December indicating that these crops probably act as a link between the rainy season and winter cereals. Napier grass, oats, sugarcane, winter maize, barley and wheat were attacked in January-February, with the highest populations (35 larvae/m^2) on Napier grass. The larval populations peaked twice, in September and February.

In Punjab, according to Bindra and Singh (1973) the larvae of *M. separata* found in field throughout the year, populations being high in

late sown and lodged wheat and in high tillering and broad leaved varieties. Saini (1987) reported that the pest was most harmful in the first two weeks of October, when the rice crop was at dough to fully ripe stage. Singh (1988) also reported damage in rice crop during October.

Host Range

Host range of *M. separata* has been reported by Helson (1970) in New Zealand, Learmonth (1981) in Australia, Wu (1982) in China, Hirai (1991) and Kanda (1997) in Japan, Ko *et al* (2002) in Korea Republic and Larry (2002) in USA. In India, Sharma *et al* (1970), Gargav *et al* (1972), Singh and Manchanda (1981), Tripathi *et al* (1982), Moray *et al* (1983), Singh *et al* (1987), Singh and Chaudhary (1988), Singh and Rai (1990), Maragal *et al* (1992), Raja Gopal and Musthak (1992), Patel and Patel (1993), Dale (1994) and Nayar *et al* (2000) reported various hosts of *M. separata*. There were 33 plant species in eight families attacked by this pest (Sharma and Davies 1983). Various crops and weeds reported as hosts of *M. separata* by different workers are listed in Table 4.

Ko *et al* (2002) in Korea Republic recorded the development and reproduction of *M. separata* on different diets namely maize, rice, Chinese cabbage, sweet potato, soybean and silkworm artificial diet. Egg and pupal periods were not different when these diets were used. But larval periods showed significant difference among diets.

Table 4: Host range of *M. separata*

Family	Scientific Name	Country/ Continent	References
Cannabaceae	*Cannabis sativa* L.	India	Sinha *et al* (1979)
Eriocaulaceae	*Erioculon sexangulare* L.	India	Gargav *et al* (1972)
Fabaceae	*Arachis hypogaea* L.	India	Rajagopal and Musthak (1992)
	Cajanus cajan (L.)	India	Rajagopal and Musthak (1992)
	Pisum sativum L.	India	Sharma *et al* (1970)
Malvaceae	*Gossypium barbedense* L.	India	Maragal *et al* (1992)
Poaceae	*Avena sativa* L.	India	Grist and Lever (1969), Tripathi *et al* (1982), Singh *et al* (1987), Dale (1994), Nayar *et al* (2000)
		USA	Larry (2002)
	Cymbopogon flexuosus Stapf.	India	Singh and Chaudhary (1988)
	Cymbopogon winterlanus Jowitt.	India	Singh and Chaudhary (1988)
	Cynodon dactylon (L.)	India	Dale (1994), Singh and Chaudhary (1988)
		Newzealand	Helson (1970)
	Eleusine coracana (L.)	India	Tripathi *et al* (1982), Rajagopal and Musthak (1992)
	Euchlaena mexicana Schras.	India	Singh and Chaudhary (1988)
	Hordeum vulgare L.	India	Singh and Rai (1989), Dale (1994)
		USA	Larry (2002)

	Pennisetum americanum (L.)	India	Moray *et al* (1983)
	Panicum antidotale Retz.	-	Dale (1994)
	Pennisetum glaucum (L.)	India	Patel and Patel (1993)
	Panicum miliaceum L.	India	Tripathi *et al* (1982)
	Panicum miliare Lam.	India	Grist and Lever (1969), Nayar *et al* (2000)
	Pennesetum purpureum S.	India	Moray *et al* (1983), Singh *et al* (1987), Singh and Chaudhary (1988), Dale (1994)
		China	Wu (1982)
	Saccharum officinarum L.	India	Tripathi *et al* (1982), Singh *et al* (1987), Singh and Rai (1989) Nayar *et al* (2000)
		China	Wu *et al* (1982)
		Australia	Learmonth (1981)
	Setaria italica (L.)	India	Tripathi *et al* (1987), Rajagopal and Musthak (1992), Nayar *et al* (2000)
	Sorghum bicolor (L.)	India	Grist and Lever (1969), Moray *et al* (1983), Singh *et al* (1987), Singh and Chaudhary (1988), Dale (1994), Nayar *et al* (2000), Kandalkar *et al* (2002)
		Japan	Kanda (1997)
	Sorghum Sudanese Stapf.	India	Singh *et al* (1987), Singh and Chaudhary (1988)

	Triticale aestivum L.	India	Grist and Lever (1969), Singh and Manchanda (1981), Tripathi *et al* (1982)
		USA	Larry (2002)
	Triticum aestivum L.	India	Singh and Rai (1989) Grist and Lever (1969), Nayar *et al* (2000)
		China	Wu (1982)
		Japan	Hirai (1991), Kanda (1997)
		Korea Republic	Ko *et al* (2002)
		New Zealand	Helson (1970)
		Australia	Learmonth (1981)
		USA	Larry (2002)

Development period from egg to adult was shortest (32.5 days) on maize leaf and longest (46.6 days) on soybean leaf. At 16 days after hatching, larval weights on rice and silkworm artificial diet were heavier than those on other diets. The larvae reared on cabbage leaf and sweet potato leaf failed to pupate. Survival rates from larva to adult were highest (70.6 percent) on maize leaf and lowest (39.8 percent) on soybean leaf. Fecundity and intrinsic rate of natural increase (rm) was maximum on maize leaf.

Singh and Rai (1990) in Uttar Pradesh reported that the first instar larvae of *M. separata* feed on rice, maize, sugarcane, wheat, barley, Bermuda grass and Johnson grass. The larvae consumed the most leaves, produced the most faecal matter and gained the most weight when fed on rice while those which were fed on sugarcane, had the second largest values for these criteria. Pupal weight was greatest in larvae fed on rice, followed by those fed on wheat and sugarcane. Rice was the most digestible crop and was most efficiently converted into body mass followed by barley. On the other hand, Bermuda grass and Johnson grass were the least favourable plants. In Gujrat, the results on the biology of *M. separata* in the laboratory on maize, sorghum and bajra indicated that the development to adulthood and total life span were longer for insects fed on sorghum than for those fed the other foods. On the other hand fecundity and the egg hatchability were greater for individuals fed on maize (Patel and Patel 1993). Ashfaq *et al*

(2000) studied the preference of host plants by *M. separata* and reported that sorghum, maize, rice, 'khabbal' grass, *Cynodon dactylon* were consumed the maximum levels, followed by sugarcane and deela (*Cyperus rotundus*). Maximum coefficient of utilization values were recorded in sugarcane, maize and rice followed by 'khabbal' grass, 'baru' grass and sorghum. No plant was found to be completely immune.

Natural Enemies

A large number of parasitoids, predators and pathogens of the rice ear-cutting caterpillar have been recorded in India and abroad. In Bangladesh, Alam (1967) recorded an ichneumoid species *Barichneumon albetorius* Fabricius as a larval parasitoid of the pest. In China, *Apanteles ruficrus* (Hal.) has been reported as an important parasitoid of larvae of *M. separata*, the percentage parasitism averaging 31-58.06 in the second generation, 37.50-50.00 in the third, 10.39 in the fourth, 20.40 in the sixth and 14.58 in the seventh generation (Wei 1982). Li (1987) reported 32-98 per cent of parasitism while Han and Gatehouse (1991) reported 80 per cent of parasitism of larvae of *M.separata.*

Rizvi and Singh (1980) in Uttar Pradesh reported that 35.8 per cent of pupae collected from field were parasitised. Those causing the highest per cent of the parasitism (8.42% in each case) were *Ichneumon* sp. and *Apanteles* sp. According to Singh *et al* (1987) in Haryana, larval

parasitism by the braconid *Apanteles* sp. was higher in September (41.2%) than February (0.6%). Charyulu (1994) reported the parasitism of larvae of *M. separata* by *Cotesia ruficrus* from late January in 1987-88 which was the highest at 74.7% on 22 March in 1987 and at 69.2% on 16 March in 1988. Sharma *et al* (2002) in Southern India reported that *Cotesia ruficrus* was the principle mortality factor, which caused upto 47% parasitism in October. Its activity was greater in sorghum (24.65) than in pearl millet (14.9%). In Punjab, Bindra and Singh (1973) reported *Apanteles ruficrus* (Hal.), *Sarcophaga orientaloides,* an undescribed species of Calliphorid, Sparrows (*Passer domesticus*) and crows (*Corvus splendens*) as natural enemies of *M. separata* on wheat. While Deol and Singh (1991) reported *Apanteles ruficrus* (Hal.) as larval parasitoid and *Calosoma indicum* as larval predator on wheat. Insects as parasitoids and predators of *M. separata* are presented / enlisted in Table 5.

Besides insects, bacteria, fungi, virus and birds also attack rice ear-cutting caterpillar. *Bacillus thuringiensis* was reported to attack the larval stages of *M. separata* by Battu *et al* (1971) and Bindra & Singh (1973). The larval infection by fungus *Nomuraea rileyi* (Farlow) in India (Kulkarni and Lingappa 2002) and *Entomophthora* sp. and *Spicaria* sp. in China (Cadapen and Sanchez 1972) is also known. Nuclear polyhydrosis virus (NPV) and a virus *Morator nudus* infection to larvae of *M. separata* was reported by Sharma *et al* (2002) in India and

Table 5: Natural enemies of *M. separata*

Stage of insect affected	Order of the class insecta	Family	Species	Country/ Continent	References
Egg parasitoids	*Hymenoptera*	*Scelionidae*	*Telenomus cirphivorus* Liu.	China	Lu (1988)
			T. chilocorus (Silvastrii.)	china	Wu *et al* (1979)
			T. dignus Gahan.	Taiwan	Chu (1979)
			T. guangdongensis Gahan.	Chian	Lu (1988), Wu *et al* (1979)
			T. parnarae Viereck.	China	Wu *et al* (1979)
		Trichogrammatidae	*Trichogramma dendrolimi* Matsumra.	China	Wang *et al* (1988)
			T. japonicum (Ashmead.)	Taiwan	Chu (1979)
			Trchogrammatoidea sp.	New Zealand	Roberts (1979)
Egg Predator	*Hymenoptera*	*Formicidae*	*Pheidole fervida* Smith.	Japan	Kanda (1987)
Larval parasites	*Coleoptera*	*Carabidae*	*Calosoma chinese* Kby.	China	Wu (1982)
			Calathus halensis (Schall.)	China	Wu (1982)
			Carabid larva	India	Khan *et al* (1972)
	Diptera	*Tachinidae*	*Compsilura sp.*	Australia	Broadley (1979)
			Corcelia excisa (Fall.)	China	Wu (1982)
			Corcelia illota (F.)	India	Sharma *et al* (2002)
			Cuphocera varia (F.)	Australia	Broadley (1979)
				China	Wu (1982)

			Dolichololon paradoxum Br. and Berg.	India	Katyar and Rawat (1972)
				China	Wei (1982)
			Exorista fallax (Mg.)	India	Katyar and Rawat (1972), Khan *et al* (1972)
				China	Wu (1982)
			Exorista japonica (Townsend.)	China	Wu (1982)
			Goniophthalmus australis (Barnov.)	Australia	Broadley (1979)
			Linnaemya compta (Fall.)	China	Wu (1982)
			Megacelia sp.	India	Sharma *et al* (2002)
			Pales pavida (Mg.)	China	Wu (1982)
			Palexorista inconspicua (Mg.)	China	Wu (1982)
			Palexorista laxa (Curran.)	India	Sharma *et al* (2002)
			Palexorista solennis Walker.	India	Sharma *et al* (2002)
			Peribae spp.	Australia	Broadley (1979)
			Siphona cristata (F.)	China	Wu (1982)
			Sturmiopsis inferens (Townsend.)	India	Sharma *et al* (2002)
			Turanogonia chinensis Wied.	China	Wu (1982)

	Hemiptera	*Calliphoridae*	*Sarcophoga orientaloides* (F.)	Punjab	Bindra and Singh (1973)
		Mermithidae	*Casnoidea indica* (Thnb.)	Taiwan	Chu (1979)
			Monomorium indicum (Forel.)	India	Rajagopal and Musthak (1992)
			Myrmicaria brunnea (Saunders.)	India	Rajagopal and Musthak (1992)
			Neoplectana feltiae (Filipja)	China	Xia and Lin (1987)
			Neoplectana sp.	India	Sharma *et al* (2002)
			Paederus fuscipes Curl.	Taiwan	Chu (1979)
			Solenopsis geminata (Fabricius)	India	Rajagopal and Mushtak (1992)
	Hymenoptera	*Braconidae*	*Apanteles ruficrus* (Hal.)	Punjab	Bindra and Singh (1973), Deol and Singh (1991)
				India	Katiyar and Rawat (1972), Rizvi and Singh (1980), Singh *et al* (1987), Charyulu *et al* (1994), Mallapur (1997), Sharma *et al* (2002),
				China	Wu (1982), Wei (1982)
				New Zealand	Hill (1986)
				Australia	Broadley (1979)
			Apateles chilonis mats	Taiwan	Chu (1979)
			Disophrys sp.	India	Katiyar and Rawat (1972)

			Meteorus sp.	China	Wu (1982), Wei (1982)
			Microplitis sp.	New Zealand	Roberts (1979)
			Rogas sp.	India	Katiyar and Rawat (1972)
				New Zealand	Roberts (1979)
			Wachsmann szigligeti L.	India	Satha (1993)
		Eulophidae	*Euplectrus separatae sp.* Nov.	Japan	Kamijo (2003)
		Ichneumonidae	*Camposcopus sp.*	China	Wu (1982)
			Charops bicolor (Szepl.)	China	Wu (1982)
			Campoletis chlenidae F.	India	Sharma *et al* (2002)
			Enicospilus sp.	India	Sharma *et al* (2002)
			Ichneumon sp.	India	Rizvi and Singh (1980)
			Litomastix sp.	New Zealand	Roberts (1979)
			Netelia sp.	China	Wu (1982)
			Vulgichneumon leucaniae (Uchida.)	China	Wu (1982), Wei (1982)
		Scelionidae	*Telenomus cirphivorus* Liu.	China	Wu (1982)
Pupal parasitoids	Hymenoptera	*Braconidae*	*Apnteles sp.*	India	Rizvi and Singh (1980)
		Ichneumoindae	*Ichncumon sp.*	India	Rizvi and Singh (1980)

by Alam (1967) in Bangladesh, Im *et al* (1989) in the Philippines and Ohbayashi and Imabuchi (1991) in Japan. In Punjab, Bindra and Singh (1973) reported that the birds namely *Passer domesticus* and *Corvus splendens* preyed also on the larvae and pupae of *M. separata*.

Chapter III

MATERIAL AND METHODS

The present studies on the biology of rice ear-cutting caterpillar *Mythimna separata* (Walker) were carried out at the Research Farms of the Department of Entomology and the Experimental Area of the Department of Plant Breeding, Genetics and Biotechnology, Punjab Agricultural University, Ludhiana.

A. MATERIAL

1. Test Variety

The seed of the popular rice variety PR 116 was obtained from the Rice Section of the Department of Plant Breeding, Genetics and Biotechnology, Punjab Agricultural University, Ludhiana.

2. Screen Houses

Insect-proof screen houses (550 x 430 x 250 cm and 305 x 215 x 255 cm) were fitted with 30 mesh galvanised wire gauge.

3. Insect Cages

i. Insect rearing cages

The cages of two sizes viz.60 x 60 x 90 cm and 65 x 50 x 50 cm fitted with 30 mesh galvanized wire gauze were used for rearing the insects.

ii. Split-cages

The split-cages (Severin 1931) of size 41 cm height and 25.5 cm in diameter were used to confine insects on potted plants for studying various aspects of the biology of rice ear-cutting caterpillar.

4. Earthen pots

The earthen pots of 20 and 25 cm diameter were used for raising test plants and for studying the different aspects of the biology of the insect.

5. Glass jars and plastic vials

The glass jars (16 x 10 cm) and plastic vials (5 x 4 cm) were used for rearing the larvae of *M. separata* on the leaves of rice. Jars and vials were covered with muslin.

6. Insect collection net

Insect collection net with a 25 cm diameter and 100 cm long bar was used for studying the seasonal abundance of the insect.

7. Light trap

The light trap was used for studying the seasonal abundance of the insect. It was operated with a 100 watt incandescent electric bulb.

B. METHODS

1. Raising of test plants

For raising nursery, seeds of rice variety PR 116 were sown at weekly intervals in earthen pots having well puddled soil . Plants were watered as and when required.One month after sowing, transplanting

was done in earthen pots having well puddled soil . The pots were watered regularly and manured from time to time to keep the plants healthy. Seedlings at different growth stages were used for various studies .

2. Rearing of *M. separata*

Various stages of *M. separata* were collected from different hosts i.e. rice, wheat, oats, maize, sugarcane etc., according to their availability. For this, faecal pellets and damage to the leaves, and ears in case of rice were observed. Damaged plants were then thoroughly searched for larvae of *M. separata*. The larvae were reared on the potted plants kept in the rearing cages. Pupae and adults, thus obtained, were used to study various aspects of biology.

3. Life cycle

Fifteen earthen pots with rice plants were placed in a water trough in which water was filled upto 2/3 level to keep away ants etc. and to provide humidity to the test plants and the test insect. A pair of laboratory reared adults was released on each pot covered with a split cage. Honey solution(10%) was provided to the adults. For this, cotton dipped in honey solution was tagged on the roof of the split-cage. Different parameters of life cycle of the insect were studied as follows.

a) Site and time of oviposition

Site of oviposition was determined by carefully observing various plant parts like leaf, leaf sheath and stem of the rice plant. The dial

oviposition activity was determined by carefully observing the number of eggs laid, every 2 hours for 24 hours till the insects died.

b) Pre-oviposition, oviposition and post-oviposition periods

The period from the day of emergence of a female to the day when it started laying eggs was taken as the pre-oviposition period. The number of days for which a female continued to lay eggs was considered as the oviposition period whereas the post-oviposition period was taken as the time interval between the termination of egg laying and death of the female. The interval between the emergence of the adult and its death was taken as the adult longevity.

c) Fecundity-cum-Hatchability

Total number of eggs laid by one female was taken as its fecundity. Number of hatched and unhatched eggs was counted in the above experiment to record fecundity-cum-hatchability.

d) Incubation period, size, shape and duration of egg stage

The duration of egg stage or incubation period was taken as the time interval between laying of the eggs and their hatching. The observations were recorded daily at 0600 hours and 1800 hours to record the incubation period. For this purpose, the observations were recorded from the experiment (3). The colour and shape of the eggs were observed. Size of the eggs was measured with the help of a compound microscope fitted with ocular micrometer and stage micrometer in the laboratory.

e) Larval period and larval instars

Time taken from the hatching of eggs to the formation of pre-pupae was taken as larval period. To study the larval period and the number of larval instars, the larvae were reared on the leaves of the rice plant. For this purpose, neonates from the experiment conducted were released singly in the plastic vials containing fresh leaves of rice. Old leaves were replaced with fresh leaves daily and larvae were transferred to fresh leaves with the help of a camel hairbrush. Change of larval instar was recorded by observing the head capsule, molted skin, colour of insect and other morphological changes, daily. Length and width of larval body as well as head were also recorded. For the measurements, ocular micrometer, stage micrometer and measuring scale were used.

f) Pupal period

When the larvae stopped feeding and became full grown, that was the start of pre-pupation, while the time taken by the larvae for the change of dirty creamy white to light brown with shiny and glossy surface was taken as the pre-pupal period. Besides the pre-pupae obtained from the above experiment, larvae collected from the field were also reared for the observation of pupal period. The time taken from the day of pre-pupal stage to adult emergence was taken as pupal period. The site of pupation was studied in the field and under screen house conditions where the culture was maintained.

h) Larval and pupal survivals

For studying larval survival, a single egg mass on a plant placed in a rearing cage was considered. Number of eggs hatched was counted and the newly hatched larvae were allowed to feed over the plant. During third instar and onwards, only five larvae per plant were kept. Plants were replaced with new plants as and when the green matter was consumed. Number of larvae pupated was noted to count per cent larval survival. Pupae obtained in various months during the conduct of experiments were counted and number of adults emerged from them were observed to calculate the per cent pupal survival.

4. Sex Ratio

The laboratory reared adults were sorted out to record the male and female individuals.

5. Number of generations

The adults from the culture were paired and released on plants kept in a rearing cage during March to October. Five such sets were maintained. Honey solution (10%) was given to the adults. Egg laying, larval development, pupation and adult emergence took place within the cage. Larvae were transferred to another plant when the green tissue of the plants decreased. Time taken from the newly emerged adults in a generation to the emergence of adults in the subsequent generation was considered as one generation. These emerged adults were again confined after pairing on the plants kept in other cages for the

continuation of second generation. This study was continued up to the end of the rice (*Kharif*) season to count the total number of generations.

6. Host range

Throughout the period of studies, gramniaceous plants and weeds were observed at weekly intervals to record the host range. Plants having faecal pellets and eaten leaves were observed carefully for the presence of larvae/pupae of the armyworm.

7. Seasonal history

To observe seasonal history, studies were carried out throughout the year. Rice as well as other crops and weeds were observed for the presence of rice ear-cutting caterpillar damage/various stages of the insect at weekly intervals. Insects collected at light trap (with 100 watt incandescent bulb) installed at the Rice Area of the Department of Plant Breeding, Genetics and Biotechnology were also observed daily for the presence of moths.

8. Natural Enemies

Eggs, larvae, pupae and adults of rice ear-cutting caterpillar were collected from the field for observing emergence of parasitoids. Leaves bearing or infested with eggs of the insect were collected and placed in glass tubes. Cotton soaked in water was placed at the bottom of the tube so that the leaves remained fresh and errect. Leaves bearing/infested with larvae were placed in glass jars. Pupae and adults were also placed separately in the jars for observing pupal and adult

parasitoids, respectively. Glass tubes and jars were covered with muslin, which was tied with the help of a rubber band to avoid escape of the insect/natural enemies. Field observations were also made to record natural enemies preying upon various stages of rice ear-cutting caterpillar.

9. Meteorological data

The data on temperature, relative humidity and rainfall throughout the period of studies were obtained from the Meteorological Observatory, Department of Agronomy and Agrometeorology, Punjab Agricultural University, Ludhiana located nearby. Maximum and minimum temperatures which prevailed in the screen-house were also recorded.

10. Statistical analysis

Mean and confidence limits were calculated for different biological parameters.

Mean $\left(\overline{X}\right) = \frac{\Sigma X}{n}$

Confidence limit (CL)

$\overline{X} \pm t_{0.05}\ s/\sqrt{n}$ (for small samples; $n \leq 30$)

Where,

X	=	an observation or variable value
ΣX	=	Sum of the observations
$\overline{X}$	=	Mean of the observations
s	=	Standard deviation
$t_{0.05}$	=	Table value of t at 5% level of significance

Chapter IV

RESULTS AND DISCUSSION

The results of the studies on the biology of rice ear-cutting caterpillar *Mythimna separata* (Walker) on rice crop conducted during the years 2003 and 2004 are presented and discussed below:

1. Life cycle of *M. separata*

Life cycle *of Mythimna separata* was studied during March-September, 2004. The observations recorded are presented (Tables 6-20) and discussed below:

A. Egg

Egg size, site and manner of oviposition : Eggs were laid singly in rows or in clusters [Plate 4.1] on the upper side of the leaves near the margins which were mostly folded later on. Similar observations were also recorded by Alam (1967), Grist and Lever (1969), Atwal and Dhaliwal (1999) Nayar *et al* (2000) and Larry (2002). However, Pandey and Tiwari (1998) observed egg laying on rice plants near the midrib of leaves. Deol and Singh (1991) reported the site of oviposition on the soil surface also in case of wheat.

Number of eggs per cluster varied from 9 to 57 with the mean of 27.92 ± 4.80 (Table 6). Nayar *et al* (2000) reported this number to be varying from 20 to 70.

(Magnified 30X)

Plate 4.1 : Eggs of *Mythimna separata* on rice leaf

Table 6: Number of eggs per cluster and size of eggs of *M. separata* during different months in 2004.

Month	Number of eggs/cluster		Size of eggs
	Range	Mean ± C.L.	Diameter (mm)
April	19-49	33.50 ± 2.35	0.61 ± 0.01
May	13-36	21.25 ± 2.17	0.60 ± 0.02
June	9-28	19.50 ± 1.77	0.60 ± 0.01
September	26-57	37.50 ± 3.10	0.59 ± 0.02
Mean	--	27.92 ± 4.80	0.60 ± 0.04

The eggs were spherical and shiny white with fine reticulations, later on turning yellow and finally brownish black. Similar observations have been reported by Dale (1994) and Nayar *et al* (2000) on rice and by Deol and Singh (1999) on wheat. However, this observation differs from Avasthi (2002) who reported the eggs to be hemispherical. Freshly laid eggs measured 0.59 to 0.61 mm with the mean of 0.60 ± 0.04 mm in diameter as shown in the Table 6. Pathak (1977) reported 0.6-0.7 mm diameter of eggs of *M.separata* but according to Grist and Lever (1969) the length and breadth of eggs was 0.5 and 0.45 mm, respectively.

Time of oviposition: Most of the eggs were laid during night, with peak period being 2.00-4.00 hours. Eggs were also laid between 4.00 - 8.00 and 18.00-00.00 hours during September-October. Data on dial oviposition are shown in Table 7. Oviposition during early evening hours and after dark has also been reported by Pathak (1977).

Duration of egg stage: The duration of egg stage was studied during different months of the rice season in 2004 (Table 8). It was 8.75 ± 0.12, 6.17 ± 0.10, 5.35 ± 0.03 and 8.92 ± 0.13 days during, April, May, June and September-October, respectively. The duration of egg stage ranged from 5-10 days, with a mean of 7.29 ± 0.21 days.

The above findings agree with those reported by Grist and Lever (1969), Pathak (1977) and Patel *et al* (1981) on rice and those of Deol and Singh (1991) on wheat for this insect. Wei (1981) in China and

Table 7 : Dial oviposition of *M. separata* during different months on rice in 2004

Time of oviposition (hrs)	April		June		September	
	No. of female(s) laying eggs	Eggs laid/female	No. of female(s) laying eggs	Eggs laid/female	No. of female(s) laying eggs	Eggs laid/female
0.00-02.00	1	38.00 (4.58)	1	32.00 (4.58)	1	51.00 (6.04)
02.00-04.00	6	94.50 (68.31)	8	53.50 (61.32)	9	40.00 (42.65)
04.00-06.00	2	75.50 (18.19)	2	42.50 (12.18)	3	35.00 (12.44)
06.00-08.00	0	0	0	0	2	45.50 (10.78)
08.00-10.00	0	0	0	0	0	0
10.00-12.00	0	0	0	0	0	0
12.00-14.00	0	0	0	0	0	0
14.00-16.00	0	0	0	0	0	0
16.00-18.00	0	0	0	0	0	0
18.00-20.00	0	0	0	0	1	46.00 (5.45)
20.00-22.00	1	39.00 (4.70)	1	37.00 (5.30)	2	39.00 (9.24)
22.00-00.00	1	35.00 (4.22)	2	58.00 (16.62)	2	56.50 (12.20)

Figures in parentheses indicate the per cent egg laying

Table 8: Duration of egg stage of *M. separata* during different months in 2004.

Month	Total no. of eggs observed	Duration of egg stage (days)	
		Range	Mean ± C.L.
April	325	7-10	8.75 ± 0.12
May	536	6-9	6.17 ± 0.10
June	248	5-8	5.35 ± 0.03
Sept-Oct.	355	7-10	8.92 ± 0.13
Mean	--	--	7.29 ± 0.21

Larry (2002) in USA also reported similar observations on rice. However, the results of our studies differ from those of Bhole *et al* (1989) who reported the incubation period to be only 3.18 days in Maharashtra and Singh and Rai (1989) who observed it to be 2.25-3.00 days in eastern Uttar Pradesh. The deviation in duration of egg stage may be due to the differences in the environmental conditions.

B. Larva

The larvae of *M. separata* passed through 6 instars [Plate 4.2]. Six larval instars have also been reported by Singh *et al* (1989), Dale (1994) and Chandrakar *et al* (2002). In the Philippines, Cadapan and Sanchez (1972) also reported 6 instars. The observations on larval instars during March-September (Tables 9 and 10) are discussed below:

Larval Instars

I Instar: Body was creamish white in colour with dark brown head. It moved by forming a loop [Plate 4.3]. Larva devoured the green tissue of leaf and converting it to a parchment like membrane. It stayed on the leaves, fed on them during night hours and migrated to leaf sheath or base of the plant during daytime. At the end of this instar, it measured 3.80 ± 0.04 and 0.34 ± 0.03 mm in length and width, respectively. Head capsule measured 0.29 ± 0.03 and 0.48 ± 0.04 mm in length and width, respectively. The duration of the first instar ranged from 2-3 days with a mean of 2.54 ± 0.38 days.

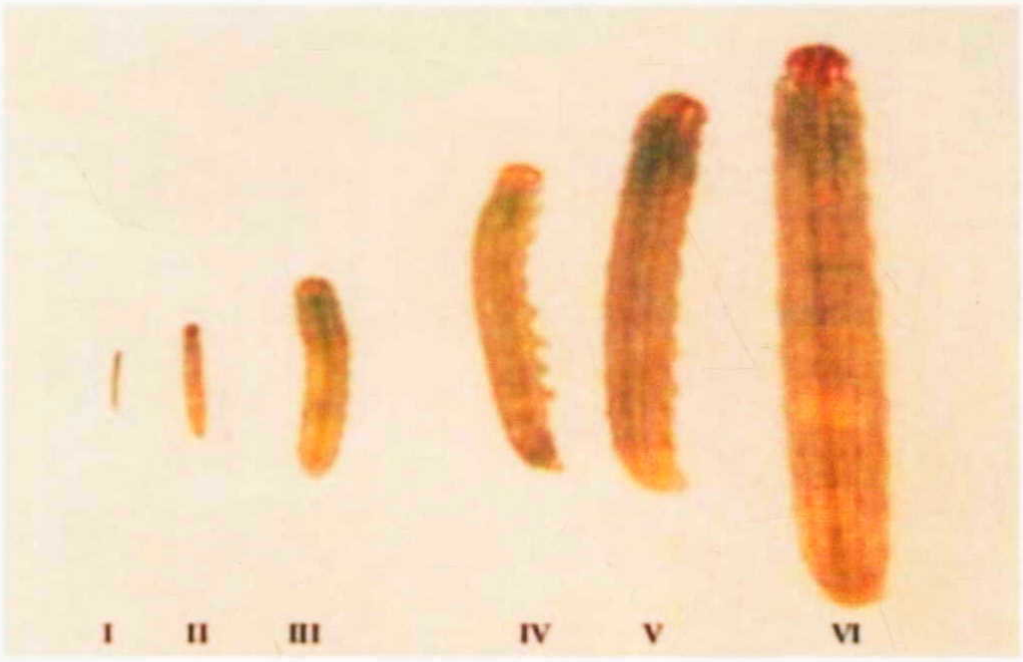

Plate 4.2 : Different larval instars of *Mythimna separata*

Plate 4.3: First instar larva of *Mythimna separata* (30 X)

Table 9 : Size (mm)* of body and head capsule of larvae of *M. separata* reared on rice during different months in 2004

Instar	Body		Head capsule	
	Length (mm)	Breadth (mm)	Length (mm)	Breadth (mm)
I	3.80 ± 0.04	0.34 ± 0.03	0.29 ± 0.03	0.48 ± 0.04
II	6.88 ± 0.18	1.12 ± 0.12	0.76 ± 0.08	1.27 ± 0.05
III	16.90 ± 0.31	2.17 ± 0.12	1.46 ± 0.19	1.96 ± 0.12
IV	25.02 ± 0.31	2.87 ± 0.18	1.82 ± 0.26	2.33 ± 0.17
V	34.32 ± 0.57	3.26 ± 0.12	2.23 ± 0.28	2.72 ± 0.13
VI	43.14 ± 0.48	4.12 ± 0.13	2.61 ± 0.30	3.37 ± 0.20

* Mean of 10 observations recorded during March-April and September-October

Table 10 : Duration and survival of *M. separata* during different months in 2004

Month	Duration of instars (days) Mean ± C.L.						Total (days)	Larval survival (%)
	I	II	III	IV	V	VI		
March-April	2.75 ± 0.18	3.50 ± 0.21	3.70±0.23	4.10±0.24	4.25±0.31	4.50±0.31	22.70 ± 0.44	92.0
April-May	2.60 ± 0.20	3.25 ± 0.23	3.30 ±0.27	3.90±0.35	4.10±0.39	5.05±0.45	21.25 ± 0.87	80.0
June-July	2.00 ± 0.15	2.55±0.17	3.20±0.18	3.50±0.21	3.85±0.22	4.75±0.23	19.85 ± 0.26	68.0
September	2.80 ± 0.21	3.75±0.23	4.10±0.29	4.45±0.32	4.65±0.35	4.90±0.39	24.65 ± 0.57	88.0
Mean	2.54 ± 0.38	3.26±0.47	3.58±0.51	3.99±0.62	4.21±0.71	4.80±0.75	22.14 ± 1.15	82.1

II Instar: Head capsule turned to a little lighter in colour. Body colour changed to light green. Larva started feeding the margins of the leaf. At the end of second instar, mean larval length and width were 6.88 ± 0.18 mm and 1.12 ± 0.12 mm, respectively. Head capsule measured 0.76 ± 0.08 and 1.27 ± 0.05 mm in length and width, respectively. The duration of this instar ranged from 3 to 4 days, with an average of 3.26 ± 0.47days .

III instar: Green colour and stripes on the body became prominent. There were four longitudinal black stripes running laterally (two on either side) with a light brown mid-dorsal stripe.It fed on leaves. At the end of this instar, the larva measured 16.90 ± 0.31 and 2.17 ± 0.12 mm in length and breadth, respectively. The length and breadth of the head capsule was 1.46 ± 0.19 and 1.96 ± 0.12 mm, respectively. The duration of third instar ranged from 3 to 5 days with an average of 3.58 ± 0.51 days.

IV instar: Green colour began to fade and black stripes became quite prominent. V shape notch is quite prominent on head capsule [Plate 4.4]. It fed on leaves, and lemma and palea of the panicle. At the end, the larva measured 25.02 ± 0.31 mm in length and 2.87 ± 0.18 mm in width. The length and width of the head capsule was 1.82 ± 0.26 and 2.33 ± 0.17 mm, respectively. The duration of the IV instar ranged from 3 to 5 days with an average of 3.99 ± 0.62 days.

Plate 4.4 : Exuviae of head capsid of fourth instar larva of *Mythimna separata* (20 X)

V instar: Body became dull green in colour. This instar cut down the panicles also along with feeding on the leaves. The larva at the end of the fifth instar measured 34.32 ± 0.57 and 3.26 ± 0.12 mm in length and width, respectively. The length and width of head capsule was 2.23 ± 0.28 and 2.72 ± 0.13 mm, respectively. The duration of the instar ranged from 4 to 6 days, averaging 4.21 ± 0.71 days.

VI instar: Full-grown larva was dusty green in colour. It cut down the panicles and caused serious damage to the crop. The larva at the end of the sixth instar measured 43.14 ± 0.48 in length and 4.12 ± 0.13 mm in width. The length and width of head capsule was 2.61 ± 0.30 and 3.37 ± 0.20 mm, respectively. The duration of the instar ranged from 4 to 6 days, averaging 4.87 ± 0.75 days.

These findings are in agreement with those of Grist and Lever (1969) who reported the full grown larval length to be 35 to 40 mm. Pathak (1977), however, reported 1.8 mm length and 0.35 mm width of first instar larvae against our measurement of 3.8 mm of length and 0.34 mm of width. Minor differences in measurements may be due to differences in rearing temperature (Deol and Singh 1991). No other systematic record on the measurement of body and head capsule is available in the literature. Besides feeding on leaves, V and VI instar larvae also cut the panicle, hence the name rice ear-cutting caterpillar. However, Pathak (1977) reported the cutting of panicles by full grown

larvae. They were negatively phototactic. No cannabalism was shown by any larval instar here, whereas, Katiyar and Rawat (1972) reported this phenomenon.

The mean duration of six instars was 2.54 ± 0.38, 3.26 ± 0.47, 3.58 ± 0.51, 3.99 ± 0.62, 4.21 ± 0.71 and 4.80 ± 0.75 days, respectively during the period March to September, 2004. There was an increase in the duration in the successive larval instars. A similar pattern has also been observed by Singh and Rai (1989) who reported it to be 1.50, 1.80, 2.60, 3.00, 3.30 and 3.40 day, respectively.

Larval duration: In the present studies, the total larval period varied from 19-26 days with an average of 22.14 ± 1.15 days during March to September. The results show that the larval duration was 22.70 ± 0.44 days during March-April. It decreased to 19.85 ± 0.26 days with an increase in temperature during June-July and again increased to 24.65 ± 0.57 days during September-October with decline in temperature.

Our findings are in agreement with Bhole *et al* (1969), Pathak (1977) and Nayar *et al* (2000) who reported the larval duration to be 23.74 days, 28 days and 23 days, respectively. In Punjab, Deol and Singh (1991) also reported larval duration of 24-28 days during March on wheat. Short larval duration during June (17-21 days) and July (18-20 days) has also been reported (on wheat) by them. In Bangladesh Alam (1967) reported 20-48 days of larval period depending upon the temperature and availability of food. In China, Wei (1982) recorded

similar observations i.e 16.5-36.5 days on rice. However, our results differ from Singh and Rai (1989) who reported the larval duration to be 15.60 days on rice and 14.25-18.50 days on *Cyperus rotundus*. The variation in larval duration may be due to different environmental conditions under which the insect was reared.

Larval survival: Survival of the larvae during March-April, April-May, June-July and September was 92, 80, 68 and 88 percent respectively with mean survival of 82.1 per cent. Reduction in survival during June-July could be due to a higher temperature.

C. Pupa

Pupation: When larva was fully developed, it stopped feeding and started spinning a web of white silken threads between the leaf sheath and the stem or in the soil. Larva became inactive and started shrinking gradually, turning creamish white with a shiny and glossy surface. No cocoon formation was there for pupation unlike those reported by Grist and Lever (1969). However, our observations are similar to those of Patel *et al* (1981) who reported pupae without cocoons between the rice tillers.

Description: The pre-pupa thus formed, gradually changed into pupa, which was shining and light brown and became reddish brown later on [Plate 4.5]. Pupa in the early stages was sensitive to disturbance. Anal segment of the pupa was converted into two long curved cremastral spines. The genital aperture was present on the 9th sternite guarded by two pads in case of males and on the 8th sternite in females [Plate 4.6].

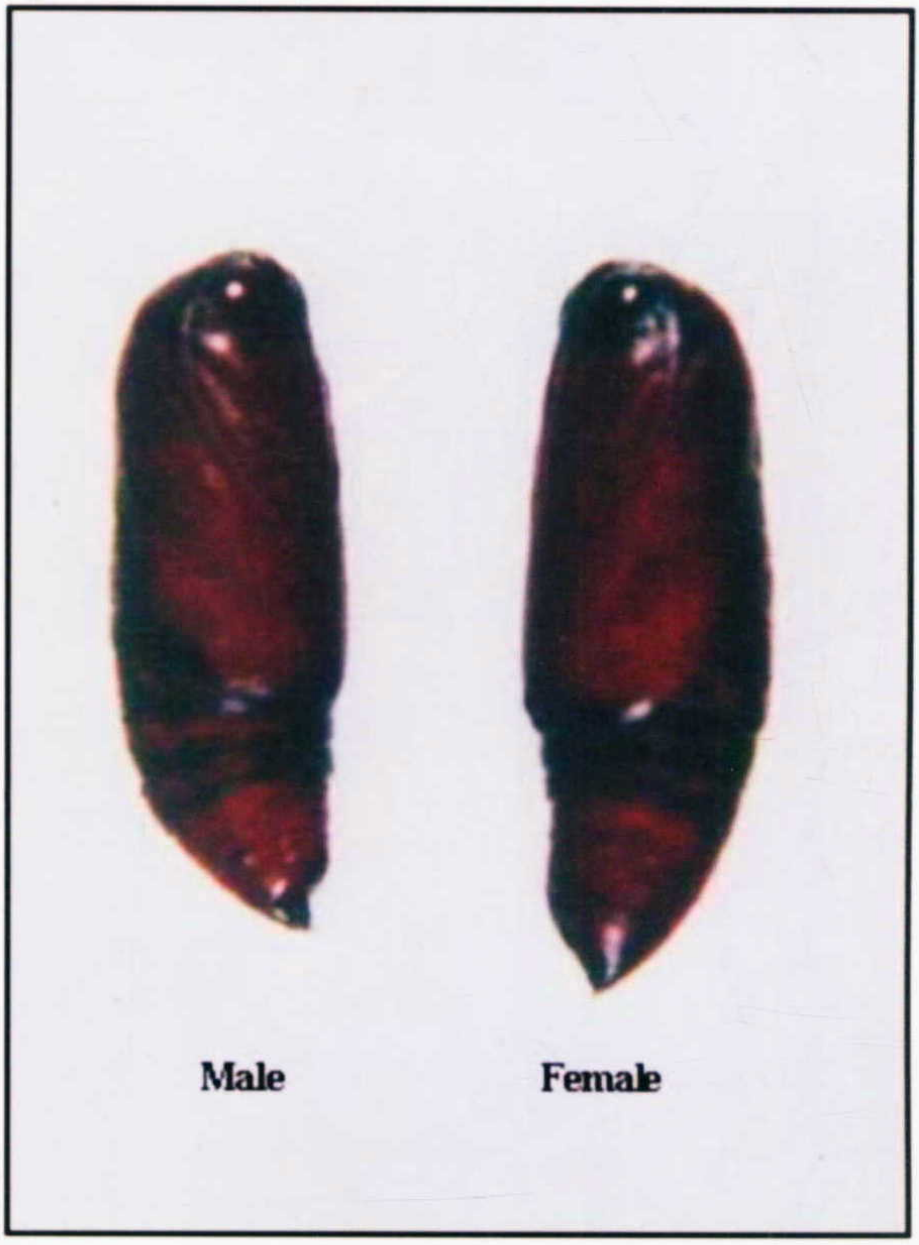

Plate 4.5 : Pupae of *Mythimna separata* (3 X)

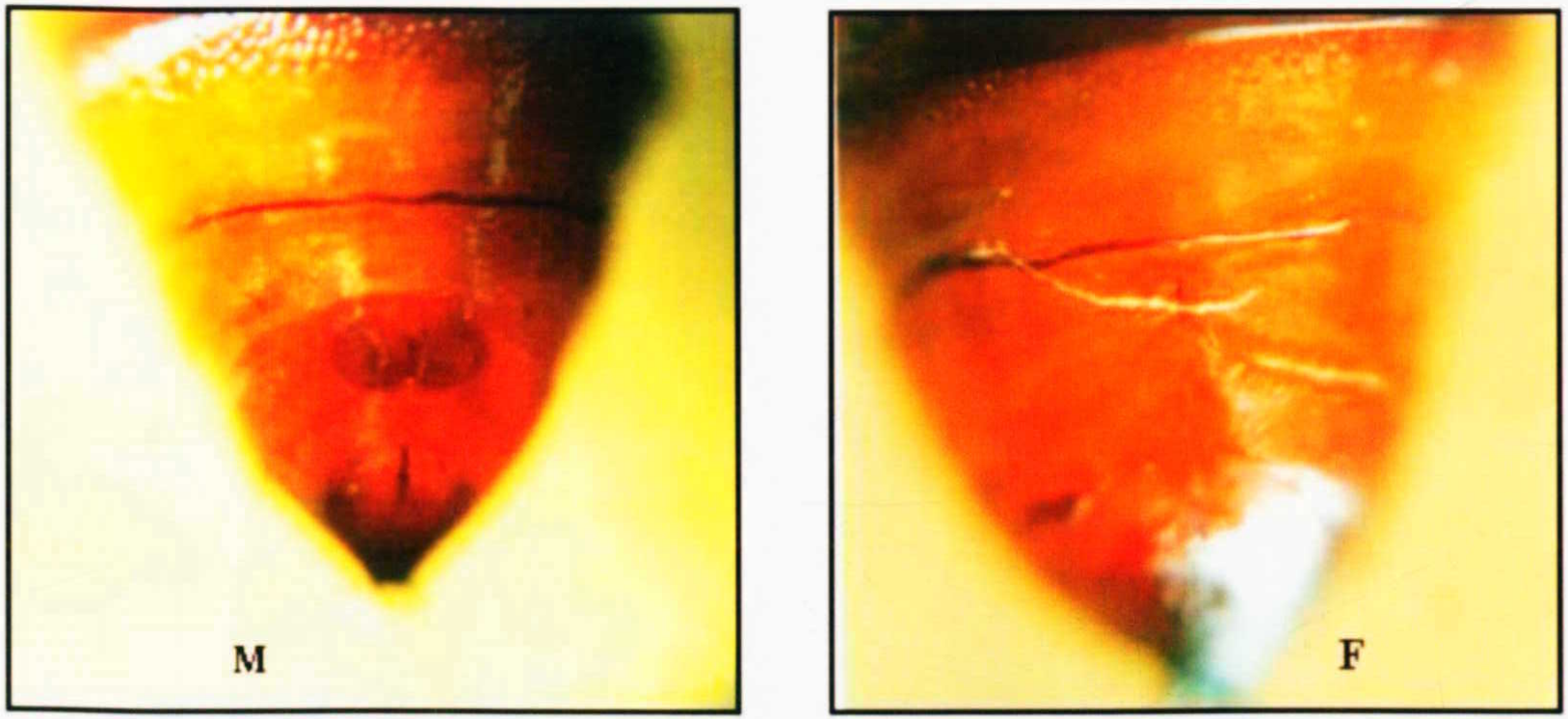

Plate 4.6 : Ventral view of male and female pupa of *Mythimna separata* (15 X)

Pupation site: Pupation site was studied both in the field and screen-house (Table 11). In the screen-house, 22.20, 26.66 and 16.60 per cent pupation was recorded in soil during March, April and June, respectively and the rest occurred in clumps of the plant. In September, 28.10 per cent pupation took place in loose soil and 71.90 per cent at the basal part of the plants in the screen-house, similar results were obtained under field conditions also. Pupation in the site was recorded at a depth of 3-5 cm. These pupation sites *viz.* between leaf sheath and stem, and in soil have also been reported by Grist and Lever (1969), Patel *et al* (1981), Deol and Singh (1991) and Nayar *et al* (2000). Deol and Singh (1991) also cited 5-7 cm as depth of soil for pupation.

Measurements: The length of the male pupa ranged from 13 to 15 mm with a mean of 14.31 ± 0.45 mm and that of female pupa ranged from 15 to 17 mm with a mean of 16.20 ± 0.28 mm. The breadth of male pupa ranged from 4.0 to 4.5 mm with a mean of 4.34 ± 0.18 mm and that of female, ranged from 4.5 to 5.5 mm with a mean of 5.04 ± 0.23 mm. No significant differences in pupal measurements were observed during the different months of study (Table 12). The female pupa was larger than male. Our observations on pupal measurements are in agreement with Grist and Lever (1969) and Avasthi (2002) who reported pupal length to be 15-19 mm. Alam (1967) in Bangladesh also reported 17 mm length and 6 mm breadth of pupae.

Table 11 : Pupation site of *M. separata* during different months in 2004

Month	No. of observations	Pupation site			
		Field		Screen house	
		In soil (%)	Inside clumps of the plant (%)	In soil (%)	Inside clumps of the plant (%)
March	10	--	--	22.20	77.80
April	15	--	--	26.66	73.24
June	12	--	--	16.60	83.40
September	25	31.50	68.50	28.10	71.90
Mean	--	--	--	23.50	76.50

Table 12 : Size (mm)* of pupae of *M. separata*

Month	Male		Female	
	Length	Breadth	Length	Breadth
April	14.22 ± 0.18	4.30 ± 0.06	16.15 ± 0.13	4.99 ± 0.14
May	14.35 ± 0.14	4.35 ± 0.09	16.20 ± 0.17	5.05 ± 0.09
June	14.37 ± 0.20	4.36 ± 0.07	16.23 ± 0.25	5.08 ± 0.16
September	14.31 ± 0.17	4.33 ± 0.08	16.22 ± 0.19	5.06 ± 0.12
Mean	14.31 ± 0.45	4.34 ± 0.18	16.20 ± 0.28	5.04 ± 0.23

* Mean ± C.L. of 20 observations

Duration: The pre-pupal period ranged from 1 to 3 days with a mean of 1.78 ± 0.29, 1.81 ± 0.32, 1.53 ± 0.17 and 2.05 ± 0.36 days during April, May, June and September, respectively. The pupal period ranged from 7 to 10 days with a mean of 7.5 ± 0.53 days in males and 8.20 ± 0.32 days in females during April. During May, pupal period also ranged from 7-10 days with a mean of 7.35 ± 0.49 days in males and 8.10 ± 0.81 days in females. In June, pupal period ranged from 6-9 days with a mean of 7.15 ± 0.87 days in males and 8.22 ± 0.48 days in females. There was an increase in pupal period during September. It was 8-11 days with a mean of 8.90 ± 0.45 days in males and 9.60 ± 0.38 days in females. The mean pupal period of male (7.81 ± 1.38 days) was less than that of female (8.61 ± 1.22 days). The overall mean pupal duration was 7.82 ± 0.7, 7.63 ± 1.02, 7.32 ± 1.18 and 9.17 ± 0.70 days during April, May, June and September, respectively (Table 13).

The observations on pre-pupal period are in agreement with those of Bhole *et al* (1989), Singh and Chaudhary (1989) and Singh and Rai (1989) who reported it to be 1.5 days, 1.7 days and 1.6 days, respectively. Atwal and Dhaliwal (1999) reported 1-11 days of pre pupal period during January to May. The observations on pupal period are in agreement with those of Bhole *et al* (1981), Patel *et al* (1981), Dale (1994) and Pandey and Tiwari (1998) who reported pupal period to be 9.05 days, 8-11 days, 8-11 days and 7-11 days, respectively. Shorter pupal period

Table 13: Duration and survival of pupal stage of *M. separata* during different months in 2004

Month	Range	Duration (days) Mean ± C.L.			Pupal survival (%)
		Male	Female	Mean	
April	7 – 10	7.50 ± 0.53	8.20 ± 0.32	7.82 ± 0.71	95.45
May	7 – 10	7.35 ± 0.49	8.10 ± 0.81	7.63 ± 1.02	84.21
June	6 – 9	7.15 ± 0.87	8.22 ± 0.48	7.32 ± 1.18	75.96
September	8 –11	8.90 ± 0.45	9.60 ± 0.38	9.17 ± 0.70	96.00
Mean	--	7.81 ± 1.38	8.61 ± 1.22	8.01 ± 1.23	87.27

during June-July (on wheat) as compared to rest of the year has also been reported by Deol and Singh (1991). However, our observations differ from those of Singh and Rai (1989) who reported the pupal period to be 4.0-6.25 days.The variation observed may be due to different environmental conditions under which the insect was reared as Alam (1967) reported the pupal period to vary from 7 to 29 days, depending upon the temperature.

Pupal Survival: The survival of pupa was 95.45, 84.21, 75.96 and 96.00 per cent during April, May, June and September, respectively. with a mean of 87.27 per cent (Table 12). Higher mortality during May and June was perhaps due to a very hot and dry weather.

D. Adult

Description: The adult of *M. separata* was profusely hairy and pale brown in colour [Plate 4.7]. Forwings were light brownish to grey in colour bearing an indistinct pale spot. Hindwings were light grey to whitish in colour. The head was brownish with dense light brown hair. Abdomen was elongated and tapering towards the end. The tibiae of the forelegs and hindlegs were tufted with straw coloured hairs which were more prominent in females. Body length and breadth of the male ranged 15.5-18.0 mm and 4.0-5.5 mm with a mean of 16.73 ± 1.47 mm and 4.86 ± 0.48 mm, respectively.

Plate 4.7 : Adults of *Mythimna separata* (2.5 X)

Body length and breadth of the female varied from 18.0 to 20.5 mm and 5.0 to 6.5 mm with a mean of 19.03 ± 1.63 mm and 6.07 ± 0.95 mm, respectively. The wing expanse of the male ranged 32-38 mm with a mean of 36.48 ± 1.21 mm while that of female ranged 45-48 mm with a mean of 46.59 ± 1.73 mm (Table 14). Thus, female moths had a larger body and wing expanse. Similar observations on wing expanse have been reported earlier(Grist and Lever 1969 and Avasthi 2002).

Adults were nocturnal in habit. They showed a little activity during the day. However, with the onset of dusk or darkness hours they became active. During day time, adults were usually located on the underside of leaves of the rice plant. They were rarely found in the light trap with an incandescent bulb (100 watt). Only 1-2 adults were observed in the light trap during March-April and September-October. Mating usually occurred during night hours (22:00-02:00 hours). Pathak (1977) reported mating to occur after dark and during evening hours.

Pre-oviposition, Oviposition and Postoviposition periods: The mean pre-oviposition period was is 2.01 ± 0.27, 1.75 ± 0.14 and 2.10 ± 0.31 days during April, May-June and September, respectively with the mean of 1.95 ± 0.53 days. The oviposition period was 3.05 ± 0.17, 2.89 ± 0.09 and 3.45 ± 0.25 days during April, May-June and September, respectively with the mean of 3.13 ± 0.39 days while the post-oviposition period was 2.72 ± 0.05, 2.03 ± 0.18 and 2.95 ± 0.15 days during the

Table 14 : Measurements of adults of *M. separata* in 2004

Month	Sex	Measurement (mm)*					
		Length		Breadth		Wing expanse	
		Range	Mean ± C.L.	Range	Mean ± C.L.	Range	Mean ± C.L.
April	Male	16-18	17.0 ± 0.51	4.5-5.5	4.9 ± 0.14	33-38	36.7 ± 0.57
	Female	18.0-20.5	19.20 ± 0.92	5.5-6.5	6.1 ± 0.52	45-48	46.8 ± 0.99
June	Male	15.5-18.0	16.95 ± 0.41	4.0-5.5	4.88 ± 0.18	32-38	36.59 ± 0.53
	Female	18-20	19.18 ± 0.63	5.0-6.5	6.09 ± 0.29	45-47	46.71 ± 1.32
September	Male	16-17	16.25 ± 0.38	4.5-5.5	4.81 ± 0.19	35-37	36.15 ± 0.42
	Female	18-19.5	18.72 ± 0.72	5.0-6.5	6.01 ± 0.33	45.5-47.0	46.25 ± 0.88
Mean	Male	--	16.73 ± 1.47	--	4.86 ± 0.48	--	36.48 ± 1.21
	Female	--	19.03 ± 1.63	--	6.07 ± 0.95	--	46.59 ± 1.73

respective months with the mean of 2.57 ± 0.27 days (Table 15). Our observations on the duration of pre-oviposition are in line with Ko *et al* (2003) who reported this period as 2.9 days at 30°C in Korea Republic. Alam (1967) in Bangladesh reported 5 days of oviposition period. No other reports could be found in the literature on the post-oviposition periods, which limits the comparison of our findings.

Adult longevity: The longevity of males ranged from 4 to 7 days with a mean of 5.46 ± 0.51 days while that of females ranged from 6 to 9 days with an average of 7.53 ± 0.35 days during March to September, 2004 (Table 15). Females lived longer than males. Longevity of adults was more in September (8.65 ± 0.20 days in females and 6.20 ± 0.27 days in males) and less in May-June (6.01 ± 0.18 days in females and 4.45 ± 0.25 days in males), the obvious reason seems to be the temperature as per results of the studies of Ko *et al* (2003) who reported adult longevity of 8 days at 30°C and 12.3 days at 15°C in the Republic of Korea.

Our observations on the adult longevity are in agreement with those of Singh and Rai (1989) who reported male and female longevity to be 5.8 days and 6.0 days, respectively. Bindra and Singh (1973) reported adult longevity to be 1-6 days. Deol and Singh (1981) reported shortest adult longevity (4-6 days on wheat in screen house) during August while in our studies on rice it was in May-June.

Table 15: Pre-oviposition, Oviposition, Post-oviposition periods and longevity of males and females of *M. separata.* in 2004

Parameter	Period (Mean ± C.L.) in days			
	April	May – June	September	Mean
Pre-oviposition	2.01 ± 0.27	1.75 ± 0.14	2.10 ± 0.31	1.95 ± 0.53
Oviposition	3.05 ± 0.17	2.89 ± 0.09	3.45 ± 0.25	3.13 ± 0.39
Post- oviposition	2.72 ± 0.05	2.03 ± 0.18	2.95 ± 0.15	2.57 ± 0.27
Longevity of males	5.72 ± 0.23	4.45 ± 0.25	6.20 ± 0.27	5.46 ± 0.51
Longevity of females	7.93 ± 0.13	6.01 ± 0.18	8.65 ± 0.20	7.53 ± 0.35

Fecundity-cum-hatchability: Fecundity and hatchability were studied during different months in 2004. The results presented in Table 16 revealed that the eggs laid per female (fecundity) ranged from 62 to 235 eggs with a mean of 131.67 ± 46.90 eggs during March-September. Per cent hatchability ranged from 62.70 per cent in June-July to 97.50 per cent in September with a mean of 79.74 percent.

The present findings on the fecundity are similar to those of Grist and Lever (1969), Dale (1994) and Avasthi (2002). Pandey and Tiwari (1998) reported the mean fecundity to be 519 eggs per female. As high fecundity as 816.6 eggs / female has been reported by in Korea (Ko 2003).

Sex ratio: Sex ratio was determined during different months of the year 2004, (Table 17). The sex ratio for male to female varied as 1.31:1, 0.78:1, 1.15:1 and 0.81:1 during April, May, June and September, respectively with a mean of 0.92:1. Singh and Rai (1989) reported it to be 1: 1 on rice.

Life cycle: The results of the present study on duration of various stages of *M. separata* summarized in Table 18 revealed that the life cycle from egg laying to adult emergence was completed in 39.27 ± 1.23 days during March-April (2004). No significant change in the duration of life cycle was observed in April-May. The life cycle duration during this period was 37.50 ± 1.19 days. During June-July, the duration of total life cycle was reduced to 32.52 ± 1.17 days.

Table 16 : Fecundity-cum-hatchability of *M. separata* during different months in 2004

Month	Fecundity		Hatching (%)
	Range	Mean* ± C.L.	
April	95-235	177.58 ± 38.65	92.05
May	82-171	151.32 ± 27.15	86.72
June-July	62-115	86.56 ± 18.03	62.70
September	65-145	111.25 ± 23.15	97.50
Mean	--	131.67 ± 46.90	79.74

Table 17: Sex ratio of laboratory reared *M. separata* during different months in 2004

Month	Sample size	Male (M)	Female (F)	Sex ratio (M:F)
April	30	17	13	1.31:1
May	57	25	32	0.78:1
June	28	15	13	1.15:1
September	49	22	27	0.81:1
Mean		--	--	0.92:1

Table 18: Life cycle of *M. separata* during different months in 2004

Month	Duration (days)*			Total life cycle (egg to adult emergence)
	Egg	Larval	Pupal	
March-April	8.75 ± 0.12	22.70 ± 0.45	7.82 ± 0.71	39.27 ± 1.23
April-May	6.17 ± 0.10	23.70 ± 0.38	7.63 ± 1.02	37.50 ± 1.19
June-July	5.35 ± 0.03	19.85 ± 0.29	7.32 ± 0.98	32.52 ± 1.17
September	8.92 ± 0.13	24.65 ± 0.57	9.17 ± 0.70	42.74 ± 1.24
Mean	7.92 ± 0.21	22.75 ± 1.15	8.01 ± 1.23	38.68 ± 2.08

Again, in September-October, the duration of total life cycle increased to 42.74 ± 1.24 days. This fluctuation in total life cycle duration could be due to differential weather prevailing during the studies. Mean duration of life cycle during March-October was 38.68 ± 2.08 days.

Similar results have been reported by Patel *et al* (1981), Pandey and Ganguly (1985) and Pandey and Tiwari (1998), who reported total duration of the life cycle to be 33-45 days, 30-36 days and 39.30 days, respectively. Singh and Rai (1989) reported a comparatively shorter life cycle (30.75 days for males and 31.25 days for female). The differences in results obtained could be attributed to different environmental conditions under which the insect was reared. For example, according to Pandey and Tiwari (1998) the duration of total development from egg to adult was 50.15, 40.29 and 36.83 days at 20, 25 and 30°C, respectively. In Republic Korea, Ko (2003) also reported 80.6 days to grow from egg to pre-adult at 15°C and 27.3 days at 30°C.

2. Number of generations of *M. separata*

Taking the time period from newly emerged adult to the emergence of adults of next generation as one generation, *M. sparata* completed five generations during March to October, 2004. The insect completed one generation from March 8 to April 17 and two generations from April 17 to July 5 on rice. Assuming one generation to be completed in 40 days, there become nearly one and half generation between July 5 to September 8, during which time study was discontinued due to non-

availability of the insect. There was one generation between September 8 and October 21 (Table 19). Taking into consideration these observations,it can be deduced that this insect completed 1-2 generation on rice and 4 generations during rice crop season. In Punjab, it has been reported that four generations are completed from October to June (Bindra and Singh 1973) and from October to mid July (Deol and Singh 1991) on wheat in the screen-house. Occurrence of 3-4 generations during rice season in Rajasthan has been reported by Patel (1979). Larry (2002) reported three generations on rice in USA. Number of generations per year has been variously reported as 5 in India (Avasthi 2002), 5 in Bangladesh (Alam 1960) and 8 in China (Wei 1982). Number of generations in a year are reported to be governed by temperature (Pathak 1977).

3. Host range of *M. separata*

Host range of *M. separata* was studied by visual observations on the symptoms of damage by observing foliage damage, cut panicles fallen on the ground and the presence of larval faecal pellets. Attempt was also made to locate different stages of the insect on other crops. Berseem (*Trifolium alexendrinum* Linn.) was recorded to be the new host during April 2004 where eggs, larval instars and their damage was observed on this crop besides already reported crops *viz.* wheat (*Triticum aestivum*), maize (*Zea mays*), oats (*Avena sativa*), sorghum (*Sorghum bicolor*), barley

Table 19: Number of generations of *M. separata* completed in 2004

Month	Crop	Duration (days) Mean ± C.L.
March-April	Rice	39.30 ± 0.81
April-May	Rice	38.09 ± 0.53
June-July	Rice	32.88 ± 0.55
Sept-Oct	Rice	42.82 ± 1.07

(*Hordeum vulgare*), bajra (*Pennisetum purpureum*) and sugarcane (*Saccharum officinarum*) as given in Table 4 in Review of literature. Oats (270 larvae/100 plants) was found to be heavily infested with this insect as compared to maize, sorghum and berseem having only 17, 3 and 27 larvae per 100 plants respectively.

4. Seasonal history of *M. separata*

Seasonal history of *M. separata* studied during March, 2003 to September, 2004 is shown in Appendix I. It was conducted by weekly collections and observations on faecal pellets, damaged leaves, cut panicles on the ground and the presence of egg clusters, larva or pupa etc. from various crops.

The results (Table 20) revealed that the rice ear-cutting caterpillar was an active pest of wheat during February to April. It was also observed on berseem (*Trifolium alexendrinum* Linn.) during April. It caused damage to oats during April-May and to maize during April - August. Some larvae were also observed, on sugarcane from May to July and on sorghum during May to August. The insect migrated to rice crop during 1st fortnight of September where it remained till October end (the attack of *M. separata* was mostly seen on the border of the rice crop). Then it shifted to winter maize/sugarcane and was seen on these crops till January end, although with low number. During the first fortnight of February, it appeared on wheat crop. Hence the insect does

Table 20 : Seasonal history of *M. separata* in 2003 and 2004

Time Period	Crop
February - April	Wheat
April	Barseem
April – May	Oats
April - August	Maize (Fodder)
May - July	Sugarcane
May - August	Sorghum
September - end October	Rice
November - February	Winter maize, sugarcane

not hibernate as larva in Punjab as it is reported to hibernate as a full grown larvae in Bangladesh (Alam 1967). Bindra and Singh (1973) also reported in Punjab that the insect was found in the field throughout the year. Singh and Rai (1990) also recorded rice ear-cutting caterpillar feeding on different cereals and grasses through out the year in eastern Uttar Pradesh. In Punjab according to Atwal and Dhaliwal (1999), the maximum population of caterpillars on wheat was observed in March. From May to February next year, the population remains rather low and the insects fed on maize, sugarcane, 'barugrass' and other crops. In Haryana, Singh *et al* (1987) reported population peaks in September on rice and in February on Napier grass. Singh and Deol (1986), Saini (1987) and Singh (1988) also reported population of *M. separata* on rice during October. Bhole *et al* (1989) in Maharashtra also reported that the population of *M. separata* peaks in October and April-May.

5. Natural enemies of *M. separata*

Eggs, larvae, pupae and adults of rice ear-cutting caterpillar were collected form various crops in the field and reared to observe the natural enemies emerging out of different stages of the insect. A parasite *Apanteles ruficrus* [Plate 4.8] and a predator *Calosoma indicum* (Plate 4.9] were observed as natural enemies of the larvae of .*M. separata*. NPV infection [Plate 4.10] and white muscardine fungus (*Beauveria bassiana*) also were also found to infect the larvae of *M. separata*. These natural enemies have already been reported in Review of literature (Table 5).

Plate 4.8 : Larva of *Mythimna separata* parasitised by *Apanteles ruficrus*

Plate 4.9 : Larval predator (*Calosoma* spp.) preyed on larvae of *Mythimna separata*

Plate 4.10 : Larva of *Mythimna separata* infected with NPV

CHAPTER V

SUMMARY

Systematic studies on the biology of *Mythimna separata* (Walker) (Lepidoptera: Noctuidae) were carried out on rice variety PR 116 in the screen houses at the Research Farms of Department of Entomology and Department of Plant Breeding, Genetics and Biotechnology, Punjab Agricultural University, Ludhiana during 2003 and 2004.

The eggs were spherical, shining white in colour with fine reticulations. The eggs were laid singly in rows / clusters on the leaves which were mostly folded later on. Number of eggs per egg cluster varied from 9 to 57 with a mean of 27.92 ± 4.80 during different months (March to September) of study. Oviposition usually took place during night with the peak period being 02:00-04:00 hours. Freshly laid eggs measured 0.60 ± 0.04 mm in diameter. The duration of the egg stage ranged 5-10 days with a mean of 7.29 ± 0.21 days during the study period. The mean egg hatchability was 79.74 per cent during March to September. The larvae passed through 6 instars during rice growing season. Body length and breadth measured 3.80 ± 0.04 and 0.34 ± 0.03, 6.88 ± 0.18 and 1.12 ± 0.12, 16.90 ± 0.31 and 2.17 ± 0.12, 25.02 ± 0.31 and 2.87 ± 0.18, 34.32 ± 0.57 and 3.26 ± 0.12 and 43.14 ± 0.48 and 4.12 ± 0.13 mm during I, II, III, IV, V and VI instars, respectively. The length and breadth of the head capsule of different instars was

0.29 ± 0.03 and 0.48 ± 0.04, 0.76 ± 0.08 and 1.27 ± 0.05, 1.46 ± 0.19 and 1.96 ± 0.12, 1.82 ± 0.26 and 2.33 ± 0.17, 2.23 ± 0.28 and 2.72 ± 0.13 and 2.61 ± 0.30 and 3.37 ± 0.20 mm during I, II, III, IV, V and VI instars, respectively. The mean duration of various instars was 2.54 ± 0.38, 3.26 ± 0.47, 3.58 ± 0.51, 3.99 ± 0.62, 4.21 ± 0.71 and 4.80 ± 0.75 days for I to VI instar larvae during March to September. Total larval period was maximum (24.65 ± 0.57 days) during September and minimum (19.85 ± 0.26 days) during June-July with the mean of 22.14 ± 1.15 days. The survival of larvae was maximum (92%) in March-April and minimum (68%) in June-July. The mean larval survival was 82.10 per cent. After emerging from the eggs, the larvae fed on soft tissue of the leaves and leaf lamina was transformed into a parchment membrane. Full grown larvae fed on the margins of the leaf lamina and at the base of the panicles and cut down the panicles.

Pupation mostly took place inside the clumps of the rice plants(76.50%). Pupation also took place in the soil (23.50%) upto the depth of 3-5 cm. The mean length and breadth of male pupa was 14.31 ± 0.45 and 4.34 ± 0.18 mm, respectively, while in case of female pupa it was 16.20 ± 0.28 and 5.04 ± 0.23 mm. The pupal period ranged from 6 to 11 days with the mean of 7.81 ± 1.38 days in male and 8.61 ± 1.22 days in case of female and the mean of two was 8.01 ± 1.23 days. The

survival of pupae was maximum (96%) during September and minimum (75.96%) during June. The mean pupal survival was 87.27 per cent.

The adults are nocturnal in habit. Mating usually occurred during night hours with the peak period of 22:00 - 02:00 hours. The male moths measured 16.73 ± 1.47, 4.86 ± 0.48 and 36.48 ± 1.21 mm in body length, breadth and wing expanse, respectively while the female measured 19.03 ± 1.63, 6.07 ±0.95 and 46.59 ± 1.73 mm, respectively.

The mean pre-oviposition, oviposition and post-oviposition was 1.95 ± 0.53, 3.13 ± 0.39 and 2.57 ± 0.27 days, respectively. The longevity of male and female adults averaged to 5.46 ± 0.51 and 7.53 ± 0.35 days, respectively. The fecundity ranged from 62 to 235 with an average of 131.67 ± 46.90 eggs per female.

The sex ratio for male: female ranged from 0.78: 1.00 to 1.31: 1.00 with the mean of 0.92: 1.00.

The total life cycle of *M. separata* from egg to adult emergence was completed in 32.52 ± 1.17 days and 42.74 ± 1.24 days during June and September. The mean time taken was 38.68 ± 2.08 days.

M. separata passed through 1-2 generations on rice crop during September-October and four generations during the rice season.

In the studies on seasonal occurrence, *M. separata* was observed to be an active pest of wheat during February-April. From april to mid May it was found on oats. Later on it shifted to maize, sugarcane,

sorghum and berseem. It migrated to rice during first fortnight of September and remained on it till end October. Later on it shifted to winter maize and sugarcane.

In the studies on host range, berseem (*Trifolium alexendrinum* Linn.) was recorded to be a new host for *M.separata.*

Apanteles ruficrus was observed to be a larval parasitoid and *Calosoma indicum* as larval predator. Nucleopolyhedrosis virus (NPV) and White Muscardine fungus (*Beauveria bassiana*) were also observed to infect the larvae of the insect.

On the basis of present studies, following suggestions emerge for the management of *M. separata* :

1. As the pest appears suddenly, regular monitoring of the crop should be done during earhead stage.
2. Highly infested fields should be flooded.
3. Insecticidal spray should be done in the afternoon, so that it effects the larvae which start climbing on the plant at night.
4. The alternate hosts of this pest should not be grown near the rice crop.
5. After harvest, the highly infested fields should be ploughed to expose the pupae in the soil.
6. The straw and stubbles of heavily infested fields should be burnt.

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APPENDIX I

SEASONAL HISTORY OF *M. separata*

Year	Month	Fortnight	No. of larval pupae/egg mass (from 100 plants)	Stage of insect observed	Crop	Crop growth stage
2003	March	I	5	2nd/3rd instar	Wheat	Earhead stage
		II	19	3rd/4th instar	Wheat	Dough stage
	April	I	0.5	Egg mass	Wheat	Maturity stage
			30	3rd/4th instar	Wheat	Maturity stage
		II	25	5th instar/pupae	Wheat	Maturity stage
	May	I	0.33	Egg mass	Oats	Maturity stage
			12	5th/ 6th instar	Oat	Maturity stage
		II	7	3rd/4th instar	Maize (fodder)	Vegetative stage
	June	I	2	4th instar/pupae	Maize (fodder)	Vegetative stage
		II	1.50	5th instar	Maize (fodder)	Vegetative stage
	July	I	0.33	3rd/4th instar	Maize (fodder)	Vegetative stage
		II	1.50	3rd instar	Sugarcane	Vegetative stage
	August	I	1	4th instar	Sorghum	Vegetative stage
		II	--	--	--	--
	Sept	I	2	2nd/3rd instar	Rice	Earhead stage
		II	1	Pupae	Rice	Earhead stage
	Oct	I	3	4th/5th	Rice	Maturity stage
		II	--	--	--	--
	Nov	I	--	--	--	--
		II	3	3rd instar	Winter Maize	Vegetative stage
	Dec	I	2	5th instar	Sugarcane, winter maize	Vegetative stage
		II	--	--	--	--

2004	Jan	I	2	4^{th} instar	Maize (fodder)	Vegetative stage
		II	2	4^{th} instar	Sugarcane	Vegetative stage
	Feb	I	12	$4^{th}/5^{th}$ instar	Wheat	Tillering stage
			5	Pupae	Wheat	Tillering stage
		II	23	$4^{th}/5^{th}/6^{th}$ instar	Wheat	Tillering stage
			7	Pupae	Wheat	Tillering stage
	March	I	20	$2^{nd}/3^{rd}/4^{th}/5^{th}$ instar	Wheat	Booting
		II	35	$3^{rd}/4^{th}/5^{th}$ instar	Wheat	Booting
	April	I	0.25	Egg masses	Berseem	Vegetative stage
			27	$1^{st}/2^{nd}/3^{rd}/4^{th}$/instar	Berseem	Vegetative stage
			155	$3^{rd}/4^{th}/5^{th}$ instar	Oats	Maturity stage
		II	145	Egg masses	Oats	Maturity stage
			270	$3^{rd}/4^{th}/5^{th}/6^{th}$ instar	Oats	Maturity stage
			12	$2^{nd}/3^{rd}$ instar	Maize (fodder)	Vegetative stage
	May	I	17	$2^{nd}/3^{rd}$ instar	Maize (fodder)	Vegetative stage
			3	3^{rd} instar	Sorghum	Vegetative stage
		II	2	3^{rd} instar	Sugarcane	Vegetative stage
	June	I	1.5	$3^{rd}/4^{th}$ instar	Maize (fodder)	Vegetative stage
		II	0.50	$2^{nd}/3^{rd}$	Maize (fodder)	Vegetative stage
	July	I	0.25	4^{th} instar	Maize (fodder)	Vegetative state
		II	2	2^{nd} instar	Maize (fodder)	Vegetative stage
	Aug	I	1	$4^{th}/5^{th}$ instar	Maize (fodder)	Vegetative stage
		II	--	--	--	--
	Sept	I	--	Eggs	Rice	Earhead stage
			15	$3^{rd}/4^{th}/5^{th}$ instar	Rice	Earhead stage (milky)
			5	Pupae	Rice	Earhead stage (milky)

		II	31	$5^{th}/6^{th}$ instar	Rice	Earhead stage (dough)
			11	Pupae	Rice	Earhead stage (dough)
	Oct	I	35	$5^{th}/6^{th}$ instar	Rice	Maturity stage
			9	Pupae	Rice	Maturity stage
		II	10	$5^{th}/6^{th}$ instar	Rice	Maturity stage
			1	Pupae	Rice	Maturity stage

APPENDIX II

Weekly Meteorological data from March to October, 2004 recorded at Meteorological Observatory of Punjab Agricultural University, Ludhiana

Month	Mean temperature (^{0}C)	Mean Relative Humidity (%)	Rainfall (mm)
March			
5-11	22.5	60	0.0
12-18	23.0	52	0.0
19-25	22.5	55	0.0
26-1	24.5	60	0.0
April			
2-8	23.4	54	0.0
9-15	28.5	90	0.0
16-22	23.4	40	5.0
23-29	27.0	42	0.0
May			
30-6	28.5	42	0.0
7-13	29.3	31	5.4
14-20	31.4	31	0.0
21-27	30.7	44	7.1
28-3	33.5	27	0.0
June			
4-10	35.3	44	0.0
11-17	34.8	39	9.4
18-24	31.3	58	10.8
25-1	30.3	75	29.4

July			
2-8	30.7	76	28.7
9-15	29.4	79	39.8
16-22	28.7	81	70.1
23-29	31.2	78	21.6
August			
30-5	28.9	85	17.8
6-12	30.4	78	30.4
13-19	30.5	81	60.0
20-26	30.4	74	13.7
27-2	29.7	83	135.2
September			
3-9	28.8	80	16.8
10-16	28.7	79	34.4
17-23	30.1	77	0.8
24-30	26.7	71	0.4
October			
1-7	25.7	63	0.0
8-14	24.7	59	0.0
15-21	24.5	59	0.0
22-28	23.3	61	0.0
29-4	22.1	64	0.0

VITA

Name of the student	:	Hardev Singh
Father's name	:	S. Joginder Singh
Mother's name	:	Smt. Kulwant Kaur
Nationality	:	Indian
Date of birth	:	10-09-1980
Permanent home address	:	Village – Ahli Kalan P.O. Kabirpur Teh : Sultanpur Lodhi, District : Kapurthala, Punjab

EDUCATIONAL QUALIFICATION

Bachelor Degree	:	B. Sc. Agriculture
University and year of award	:	Punjab Agricultural University (200
OCPA / % of marks	:	7.78 / 10.00
Master's Degree	:	M. Sc. Entomology
University and year of award	:	Punjab Agricultural University, Ludhiana, (2005)
OCPA 247519	:	8.01/10.00
Title of Master's Thesis	:	"Biology of *Mythimna separata* (Walke (Lepidoptera : Noctuidae) on Rice Crop"
Awards/ Distinctions/ Fellowships/Scholarships	:	Monsanto Merit Scholoarship during 2003-2004 University Merit Certificate In Folk Dance (Bhangra)