Chapter-IV

OBSERVATIONS

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4.1. Occurrence of Insect Pests of Stored Pulses and their Parasitoids at Terai Agro-climatic Condition

4.1.1. The species of *Callosobruchus* recorded

A district wise occurrence of insect pests of the genus *Callosobruchus* of stored were recorded. The data are furnished in **Table 7** and **Appendix XI.** The photographs of the insect pests are furnished in **Plate 4.**

It was found that *C. chinensis* were the most abundant and destructive insect pest of green gram, lentil, red gram and grass pea. The pest also caused damage to chick pea, cowpea, pigeon pea, Indian bean, moth bean, horse gram and pea. *C. analis* is also harmful to green gram followed by black gram, thakri kalai, cowpea, pigeon pea and grass pea. The buggy pea beetle, *C. pisorum* was recorded only on pea and their infestation occurred in the field and adult emerged out after few months in the storehouses **(Plate 6)** The insect, however, couldn't complete its life cycle in stored peas. *C. maculatus* was obtained from all the places of collection and infestation was moderate **(Table 7)**.

Table 7. District wise distribution of pests and their infestation
(Recorded during 1999, 2000 and 2001)

Name of the Pulses	Insect pest species (Scientific name)	Name of the district			
		Cooch Behar	Jalpaiguri	Darjeeling	Uttar Dinajpur
Green gram (*Vigna radiata*)	*C. chinensis* L.	M+++	M+++	M++	M+++
	C. maculatus	M++	M+	M+	M+
	C. analis	M++	M++	M+	NR
	Sitophilus sp.	T	T	NR	T
	Corcyra cephalonica	T	NR	NR	NR
Chickpea (*Ciser arietinum*)	*C. chinensis*	M++	M++	M+	M+
	C. maculatus	M+	M+	M+	M+
	Sitophilus sp.	T	T	NR	NR
	Corcyra cephalonica	T	NR	NR	NR
Black gram (*V. mungo mungo*)	*C. analis*	M+++	M+++	M+	NR
	C. maculatus	M++	M++	M++	M++
	C. chinensis	M++	M++	M+	M+
Thakri kalai (*V. mungo silvestries*)	*C. analis*	M+++	M+++	M+	NA
	C. maculatus	M++	M++	M+	M++
	C. chinensis	M++	M++	M++	M++
Grass pea (*Lathyrus sativus*)	*C. chinensis*	M+++	M+++	M++	M+++
	C. analis	M+	NR	NR	NR
	C. maculatus	M++	M+	M+	M+

Name of the Pulses	Insect pest species (Scientific name)	Name of the district			
		Cooch Behar	Jalpaiguri	Darjeeling	Uttar Dinajpur
Pea (*Pisum sativum*)	*C. chinensis*	M+	M+	T	M+
	Sitophilus sp.	T	T	NR	NR
	C. pisorum	T	NR	T	NR
Lentil (*Lens esculentum*)	*Sitophilus* sp.	T	T	NR	NR
	C. chenensis	M+++	M+++	M++	M++
	C. maculatus	M+	M+	M+	M+
Cowpea (*Vigna catiang*)	*C. chincnsis*	M+	M+	M+	M+
	C. analis	M+	T	NR	NR
	C. maculatus	M+++	M++	M++	M+
Horse gram (*Dolicos biflorus*)	*C. chinensis*	M+	M+	NR	NR
	C. analis	M+	M+	NR	NR
	C. maculatus	M+	M+	NR	NR
Soybean (*Glycine max*)	Bruchid eggs	T	T	T	NR
Kidney bean (*Phaseolus vulgaris*)	Bruchid eggs	T	NR	NR	NR
Red gram (*Cajanus cajan*)	*C. chinensis*	M+	M+	T	M+
	C. analis	M+	NR	NR	NR
	C. maculalus	M+	M+	NR	NR
	Sitophilus sp.	T	T	NR	NR
Small pea (*Pisum arvense*)	*C. pisorum*	T	T	T	NR
Moth bean (*Vigna aconitifolia*)	*C. chinensis*	M+	M+	NR	NR
Indian bean (*Dolicos lab lab*)	*C. chinensis*	T	T	NR	NR

+ = Presence of eggs on the seeds of stored pulses.
M+++ = Maximum egg-infestation on seeds (above 25%)
M++ = Moderate egg-infestation on seeds (10-24%)
M+ = Minimum egg-infestation on seeds (4-9%)
T = Trace egg-infestation on seeds (below 5%)
NR = No egg-infestation on seeds

4.1.2. Parasitoids recorded

A few minute hymenopteran bio-control agents were found with the bruchid pests. Three parasitoids of bruchids and two of other host insects pests were recorded from this area of investigation. The parasitoid *Uscana mukerjii,* is an egg parasitoid of *C. chinensis* and *C. analis*. It was found to be a potential bio-control agent (**Plate 11**). Another larval-pupal gregarious ecto-parasitoid, *Dinarmus vagabundus* was also collected from *C. analis* on stored black gram (*Vigna mungo mungo*). Another species of *Dinarmus* also recorded on bruchids infested stored red gram. The district wise occurrence of the natural enemies and their hosts are furnished in **Table 8, Plate 5** and **Appendix XI.**

Table 8. The district wise distribution of parasitoids
(Record of 1999, 2000 and 2001)

Parasitoid	Host insect	Storage pulse	Occurrence
Dinarmus vagabundus **(Timb.)** **(Hymenoptera : Pteromalidae)**	*C. chinensis* Linn. & *C. analis* Fabr.	Black gram (*Vigna mungo* & *V. mungo silvestries*)	Coochbehar, Jalpaiguri
Dinarmus **sp.** **(Hymenoptera : Pteromalidae)**	*C. maculatus* Fabr. *C. chinensis* Linn.	Red gram (*Cajanus cajon*)	Coochbehar, Jalpaiguri Darjeeling, Uttar Dinajpur
Cercocephala dinoderi **Gahan** **(Hymenoptera : Pteromalidae)**	*Sitophilus* spp.	Green gram (*Vigna radiata*)	Coochbehar
Bracon **sp.** **(Hymenoptera : Braconidae)**	*C. cephalonica* Staint.	Green gram (*Vigna radiata*)	Coochbehar
Uscana mukerjii **(Mani)** **(Hymenoptera : Trichogrammatidae)**	*C. chinensis* Linn. *C. analis* Fabr.	Green gram & Black gram	Coochbehar, Jalpaiguri
Uscana mukerjii **(Mani)** **(Hymenoptera : Trichogrammatidae)**	*C. chinensis* Linn. *C. analis* Fabr.	Green gram & Black gram	Coochbehar, Jalpaiguri

4.1.3. Extent of infestation and damage caused by the bruchids
(Recorded during 1999-2001)

This observation involved the estimation and assessment of the per cent seed damage (**Table. 9** and **Plate 6**) and quantitative weight loss (**Table 10**) caused by different species of pests on stored pulses.

Table 9. Estimation of per cent damage
(Average of 3 seasons, 1999-2001)

Pulses	Insect pests	Damage (%)			Average of 3 seasons
		Winter	Summer	Rainy	
Green gram	*C. chinensis*	22.85	30.33	36.66	29.94
	C. analis.	16.04	18.12	17.39	17.18
	C. maculatus	15.49	17.11	16.19	16.26
Black gram	*C. chinensis*	-	-	2.29	00.76
	C. analis	19.43	15.93	16.42	17.26
	C. maculatus	20.91	19.12	19.62	19.88
Red gram	*C. chinensis*	17.92	16.22	21.92	18.68
	C. maculatus	18.29	19.03	19.92	19.08
Horse gram	*C. chinensis*	13.45	14.90	15.02	14.45
Bengal gram	*C. chinensis*	9.75	12.87	22.49	15.03
Lentil	*C. chinensis*	33.66	45.27	46.01	42.64
Pea	*C. chinensis*	10.02	08.14	13.58	10.58
Cowpea	*C. chinensis*	13.59	13.01	15.06	13.88
	C. maculatus	19.02	20.13	19.92	19.69

Pulses	Insect pests	Damage (%)			Average of 3 seasons
		Winter	Summer	Rainy	
Thakri kalai	*C. analis*	16.92	15.37	16.85	16.38
	C. chinensis	-	-	3.12	01.04
Grass pea	*C. chinensis*	21.4	21.42	24.44	22.42
	C. maculatus	12.11	14.99	14.87	13.99
Soybean	*Callosobruchus* sp.	-	-	-	-
Kidney bean	*Callosobruchus* sp.	-	-	-	-
Moth bean	*C. chinensis*	22.22	21.5	29.98	24.56
Small pea	*Callosobruchus* sp.	-	-	-	-

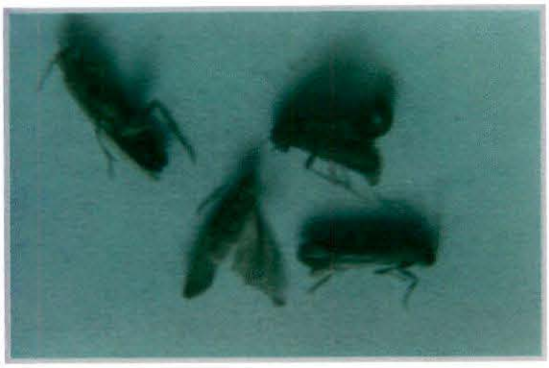
The percentage of damage of stored pulses (Table 9) by *C. chinensis* was the highest (average of 3 seasons). Damage of lentil was 42.6%, grass pea 22.4%, green gram 29.4%, red gram 18.6%, cow pea 13.8%, horse gram 14.45, chick pea 15.03% , pea 10.5% , black gram 00.7% and thakri kalai was 1.04%. Estimation of damage (%) caused by *C. analis* recorded maximum on black gram (17.2%) and thakri kalai (16.3%) whereas *C. maculatus* caused maximum damage on cow pea, pigeon pea, black gram, grass pea and green gram (**Table 9**). These bruchids could not damage stored soybean (*Glycine max*), kidney bean (*Phaseolus vulgaris*) and small pea (*Pisum arvence*) seeds (**Fig.1**). The highest damaged was caused during rainy season followed by summer and winter. The damage caused by *C. analis* on black gram was 17.2%, thakri kalai 16.3% and green gram 14.1%.This bruchid could not able to damage lentil, soybean, kidney bean and small pea (**Fig.1**). Quantitative weight loss (%) of stored peas by *Callosobruchus* (=*Bruchus*) *pisorum* was the highest (17.08%) followed by *C. analis* and *C. chinensis* (**Table 10** and **Fig. 2**).

Table 10. Estimation of per cent weight loss

(Average of 3 seasons, 1999-2001)

Pulses	Insect pests	Loss of wt. (%)			Average of 3 seasons
		Winter	Summer	Rainy	
Green gram	*C. analis*	11.73	12.51	14.95	13.06
	C. chinensis	10.36	11.83	14.15	12.11
Grass pea	*C. chinensis*	05.72	07.78	09.98	07.82
	C. analis	07.42	10.11	12.11	09.80
Pea	*C. chinensis*	03.79	04.11	05.42	04.40
	C. analis	06.87	07.78	09.02	07.89
	C. pisorum	15.13	17.79	18.21	17.08
	Sitophilus sp.	01.64	01.21	02.27	01.70
Black gram	*C. analis*	10.37	11.26	11.39	11.00
Cowpea	*C. chinensis*	10.03	11.79	12.68	11.50
	C. analis	09.20	12.42	14.21	12.60
Bengal gram	*C. chinensis*	10.42	11.20	12.42	11.30
Red gram	*C. chinensis*	07.21	09.21	10.42	08.94
Lentil	*C. chinensis*	16.63	18. 74	19.42	18.20
	C. analis	-	-	-	-

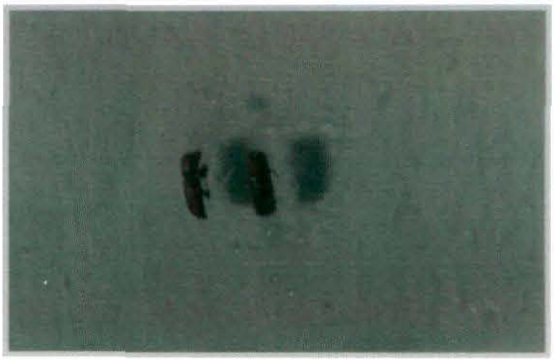
PLATE 4



Grain moth,
Corcyra cephalonica Stainton
(Lepidoptera: Galleriidae)

Grain weevil,
***Sitophilus* sp.**
(Coleoptera : Curculionidae)

Pulse beetle,
Callosobruchus chinensis Linn.
(Coleoptera: Bruchidae)



Red floor beetle,
Tribolium sp.
(Coleoptera : Tenebrionidae)

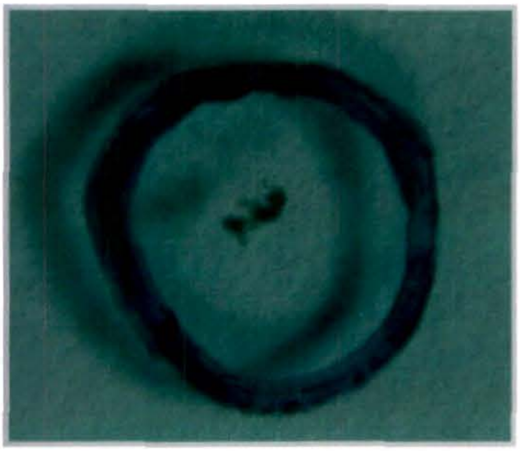
Pea buggy weevil,
Callosobruchus pisorum Linn.
(Coleoptera : Bruchidae)

Callosobruchus analis Fabricious
(Coleoptera : Bruchidae)

Photoplate 4. Insect-pest of stored pulses

Egg-parasitoid of pulse beetle,
Uscana mukerjii (Mani)
(Hymenoptera:Chalcidoidea:Trichogrammatidae)

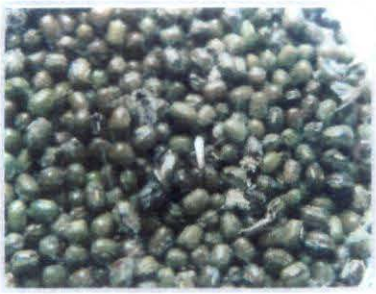
Larval parasitoid of grain moth,
***Bracon* sp.**
(Hymenoptera:Ichneumonoidae:Braconidae)



Larval-parasitoid of grain weevil,
Cerocephala dinoderi Gahan
(Hymenoptera:Chalcidoidea:Pteromalidae)

Larval-pupal ectoparasitoid of pulse beetle,
Dinarmus vagabundus (Timberlake)
(Hymenoptera:Chalcidoidea:Pteromalidae)

Photoplate 5. Natural enemies of insect-pest of stored pulses



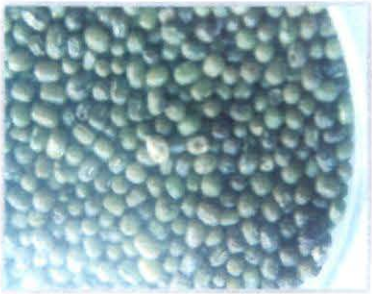
Stored green gram
(*Vigna radiata* L.) infested by grain moth, *Corcyra cephalonica* Stainton.

Egg infestation of pulse beetle on soybean (*Glycine max* Merr.)

Storage pea
(*Pisum sativam* L.)
damaged by *C. pisorum* L.

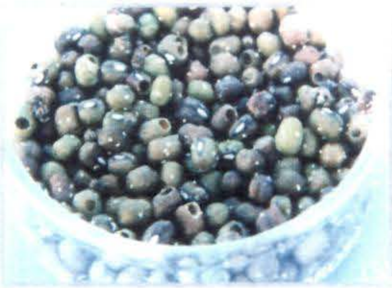
Red gram
(*Cajanus cajon* Milsp.)
damaged by *C. chinensis* L.

Grass pea
(*Lathyrus sativus* L.)
damaged by *C. chinensis* Linn.



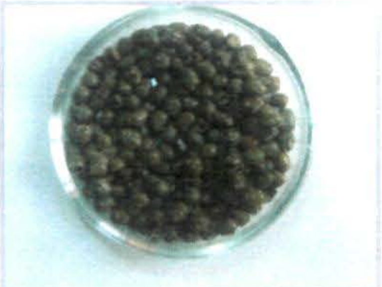
Green gram
(*Vigna radiata* L.)
damaged by *Sitophilus* sp.L.

Black gram
(*V. mungo silvestries* L.)
damaged by *C. analis* Fab.



Green gram
(*V. radiata* L.)
damaged by *C. chinensis* L.

Kidney bean
(*Phaseolus vulgaris* L.)
infested by *Callosobruchus* sp.



Green gram
(*V. radiata* L.)
damaged by *C. analis*

Pea
(*Pisum sativum* L.)
damaged by *C. chinensis* Linn.

Photoplate 6. Infested/damaged stored pulses

Fig 1. Damage (%) of stored pulses by *C. chinensis*

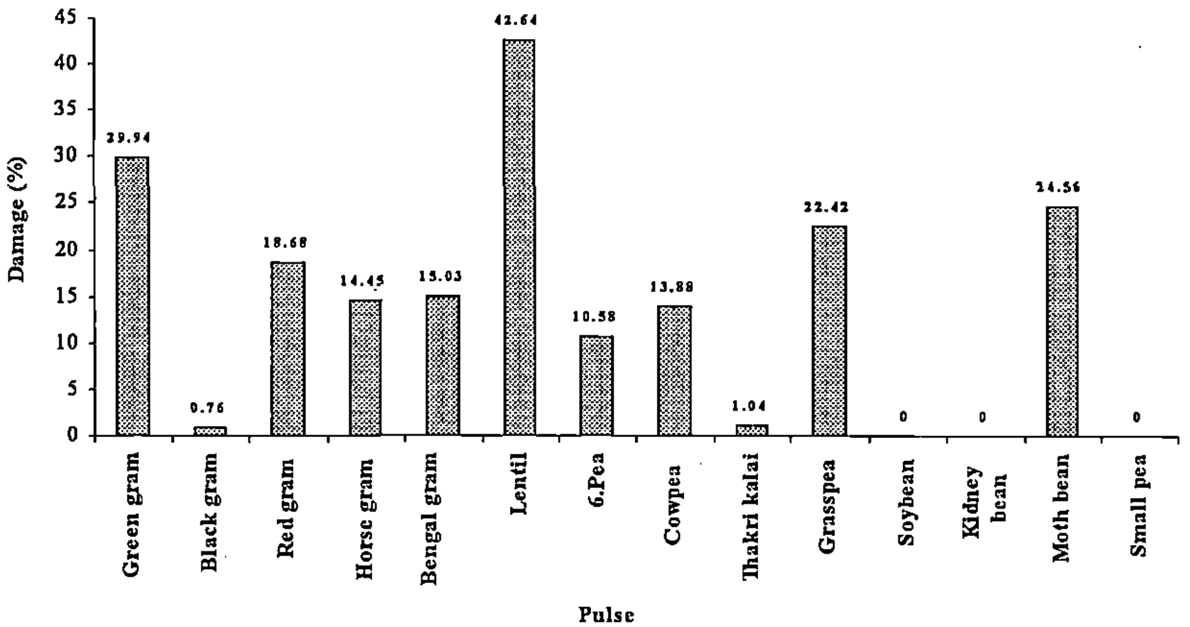
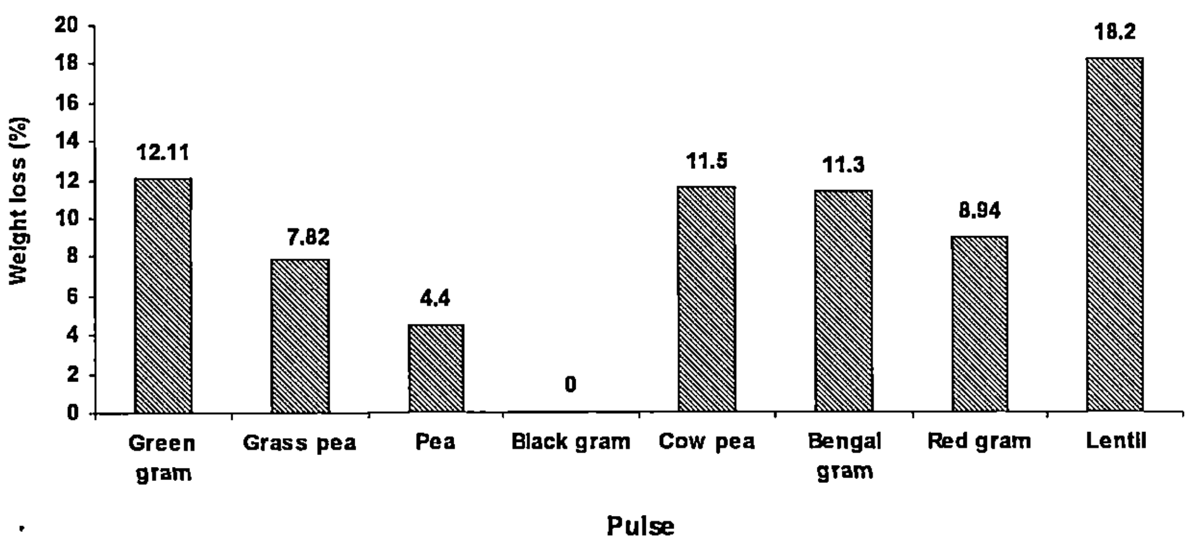
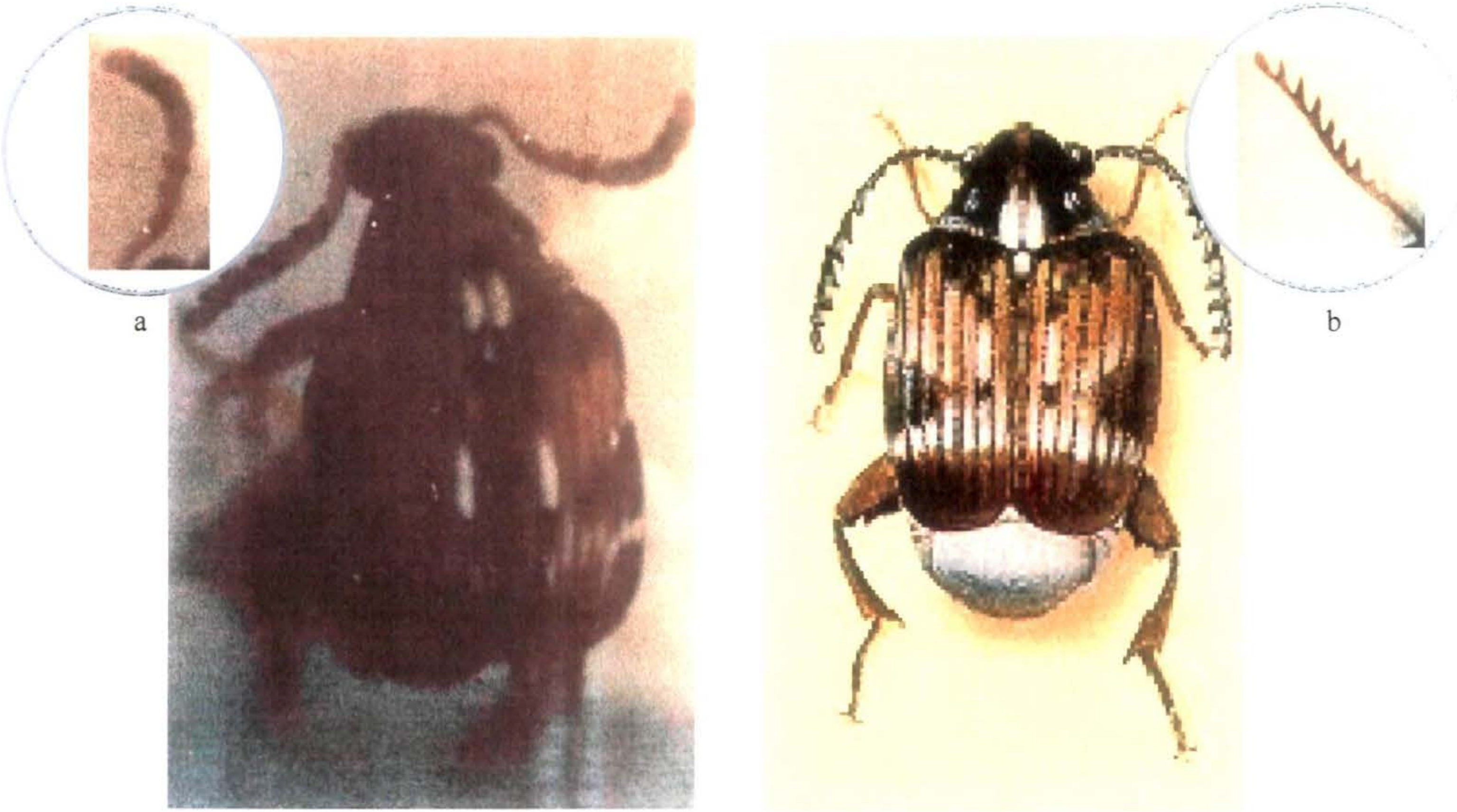


Fig.2. Weight loss (%) of stored pulses due to *C. chinensis*





Female Male

Photoplate 7. ***Callosobruchus chinensis*** **Linnaeus**
(**Inset :** a. Female antanae b. Male antanae)

4.2. Bio-ecology of C. *chinensis* on green gram in the laboratory

The eggs were oval, plano-convex and broad anteriorly, narrow at the posterior. The freshly laid eggs were transluscent, milky-white with yellow tinge and smooth. The eggs later become pale yellowish or grayish. Newly emerged adults of same age were found to mate within an hour during summer or took a maximum of three hours during winter. The adults were polygamous. After mating the females were laid eggs singly if the seeds were found to be sufficient but if the seeds are insufficient then it laid maximum up to six on a single green gram seed.

These observations (**Table 11**) were taken from eleven sets of different temperature and relative humidity on monthly basis (**Table 12**).

4.2.1. Oviposition period

A prolonged oviposition period from 11 to12 days was observed during January - March. It was only 6 to 9 days (mean 7.5 days) during November - December, 6-8 days (mean 7.0 days) during March - April and 5-7 days (mean 6.25 days) during October - November. The shortest oviposition period from 4 to 5 days (mean 4.25 days) was observed during May. During the major period of the year the duration was from 4 to 6 days.

4.2.2. Incubation period

It was prolonged, 9 to 12 days (mean, 10.75 days) and 7 to 10 days (mean, 8.75 days) during January-February and November-December respectively. The period shortened during March-April (4.75 days) and April-May (3.75 days).The shortest incubation period was observed during May (3.5 days). From May- June to October-November the period ranged from 4.25 to 6.62 days).

4.2.3. Larval-pupal duration

The mean duration ranged between 18.55 and 36.50 days. The longest duration was during January-February and the shortest during June-July, the values were 34-37 and 16-22 days respectively.

4.2.4. Developmental period

The values were similar to the combined values of incubation and larval-pupal durations. The pest took as long as 47.25 days during January-February and the shortest of 22.75 days during May.

4.2.5. Longevity of adult

Longevity of adult males' during January-February differed significantly from that of other periods. During this period the mean life span was 14.10 days which was the maximum life span within a year. Shortest life span of 7.27 days was during May. During the period from April to June the span of three generations did not differ. Again, during June-December the life span did not differ significantly.

Life span of adult female was always shorter in comparison to that of the adult males.. Prolonged life span of females was 11 to 14 days with a mean of 12.00 days during January - February followed by 7 to 10 days during November - December and 7 to 9 days during March - April and July - September. The shortest longevity of adult females was 6 to 9 days during May with a mean of 6.50 days.

4.2.6. Sex ratio

Sex ratio (female : male) showed very little differences in different generations of a year. In general, the females were of less number than the males. During Aug. - Sep. the female and male ratio was 1: 0.52.

4.2.7. Fecundity

There were differences in fecundity in different generations of a year. The highest fecundity was recorded during June-July with a mean of 95.62. The lowest was during November - December with a mean of 64.09. In other generations of a year the values were 93.81 (March - April), 93.22 (July - August), 89.66 (May), 88.5 (April - May), 85.2 (May - June), 79.0 (Jan. - Feb.) and 75.37 (Aug. – September).

4.2.8. Hatchability

The hatchability (%) of eggs laid by *C. chinensis* on green gram seeds was the highest of 78.45 during March - April followed by 67.7 (Jan. - Feb.), 66.75 (April - May), 59.1(May), 51.88 (May - June) and 51.27 (October - November). It was below fifty percent during other months. The Lowest hatchability was observed during July-August when the percentage was 39.27 only.

4.2.9. Adult Emergence

The adult emergence (%) of *C. chinensis* varied in different months. Mean adult emergence percentage was in the following descending order 64.2% (April - May) > 53.7% (Mar. - April) > 47.74% (May) > 41.29% (Jan. – Feb.) > 41.15% (Nov. –Dec.) > 31.01 (Oct. – Nov. > 29.91% (May - June) > 26.5% (Sept.- Oct.) > 23.54% (Aug. –Sept.) > 23.19% (July – Aug.) > 21.1% (June – July).

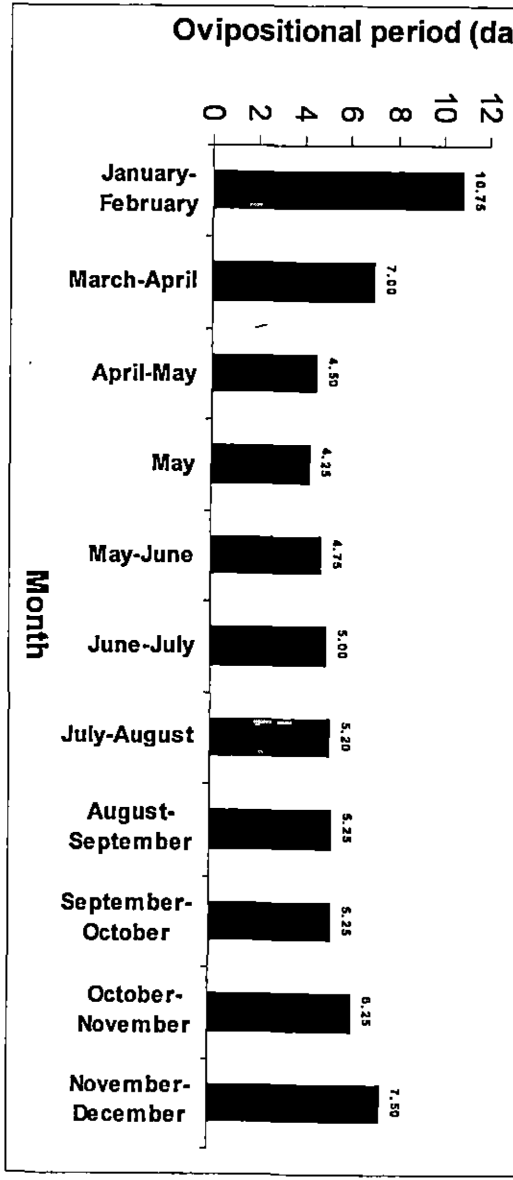


Fig. 3. Ovipositional period of *C. chinensis*

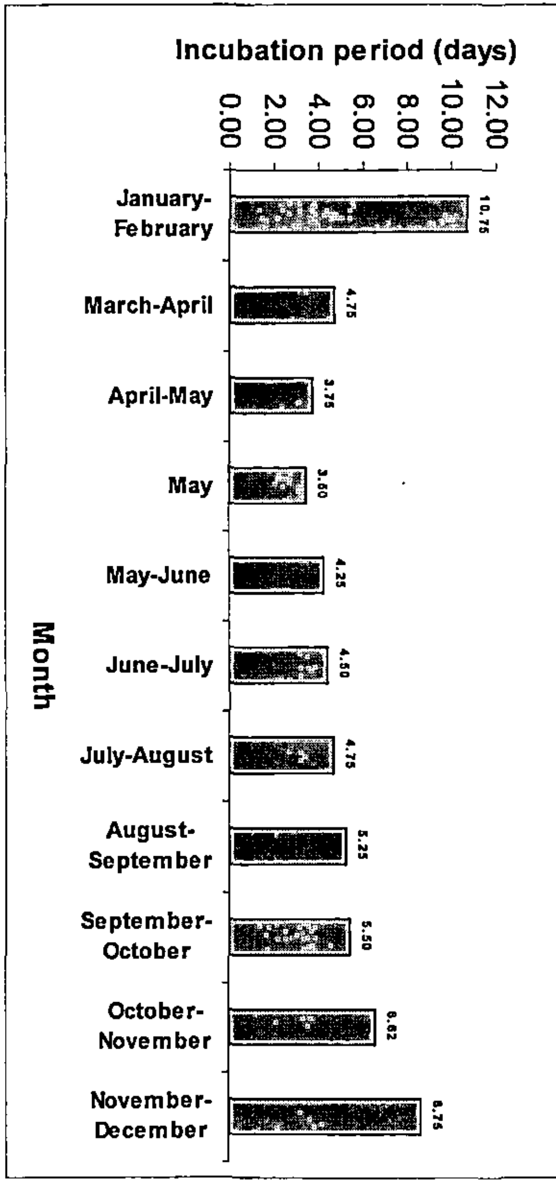


Fig. 4. Incubation period of *C. chinensis*

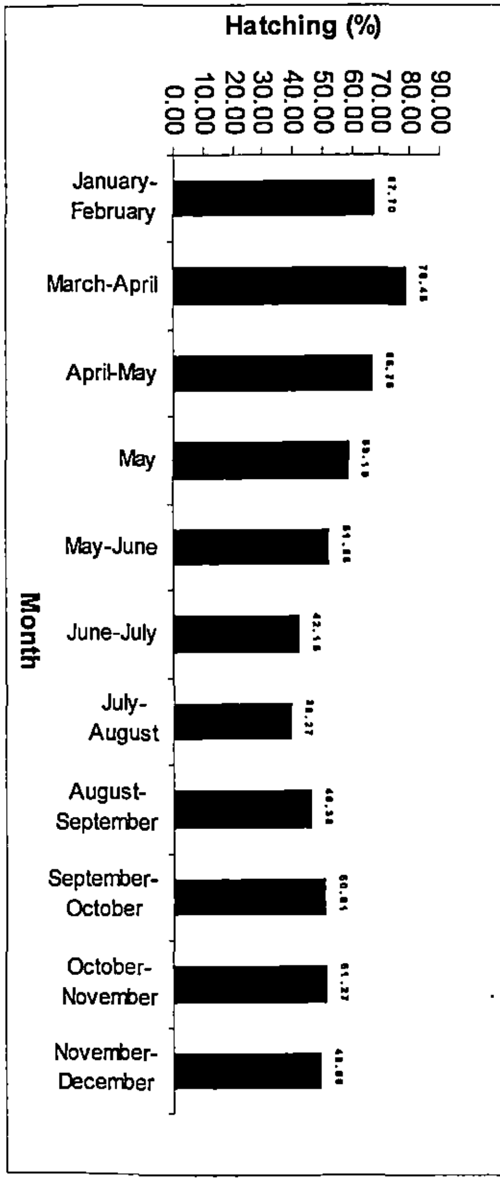


Fig.5. Hatchability of *C. chinensis*

Fig.6. Larval-pupal period of *C. chinensis*

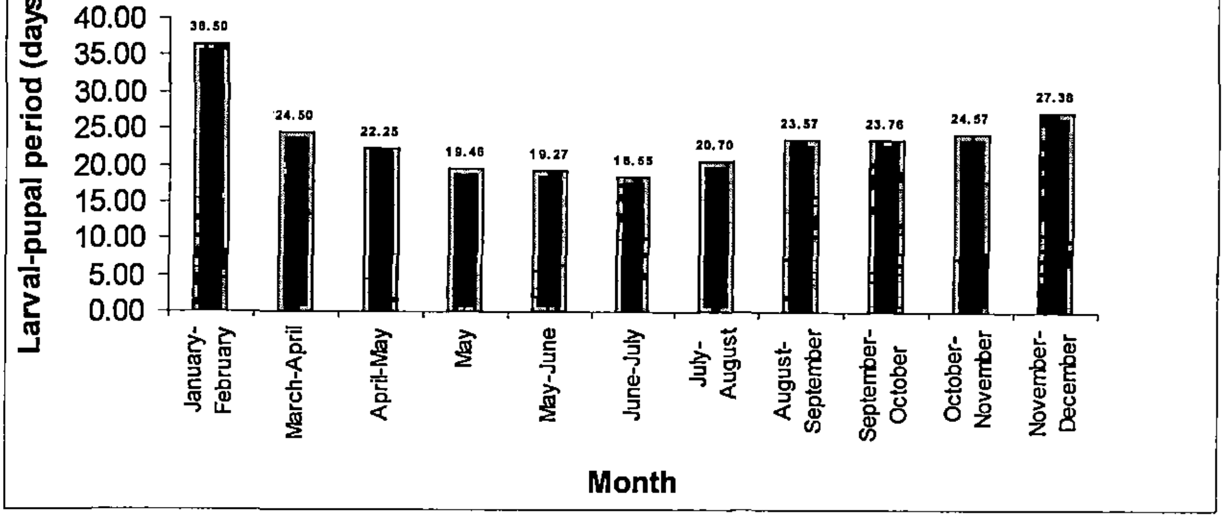


Fig. 7. Longevity of adult C. chinensis

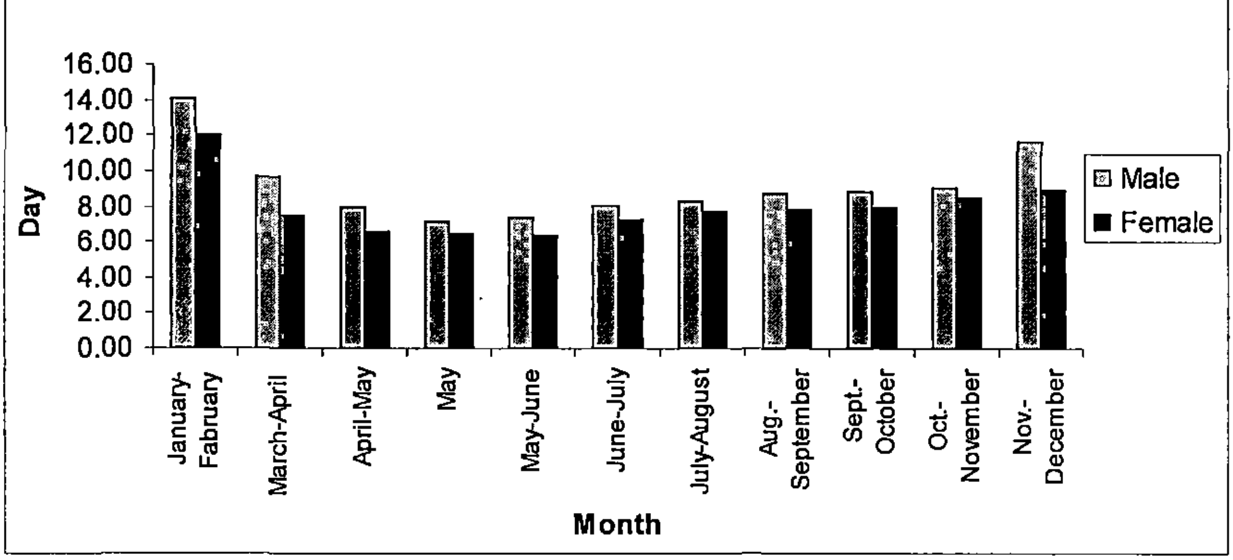


Fig.8. Total development period of *C.chinensis*

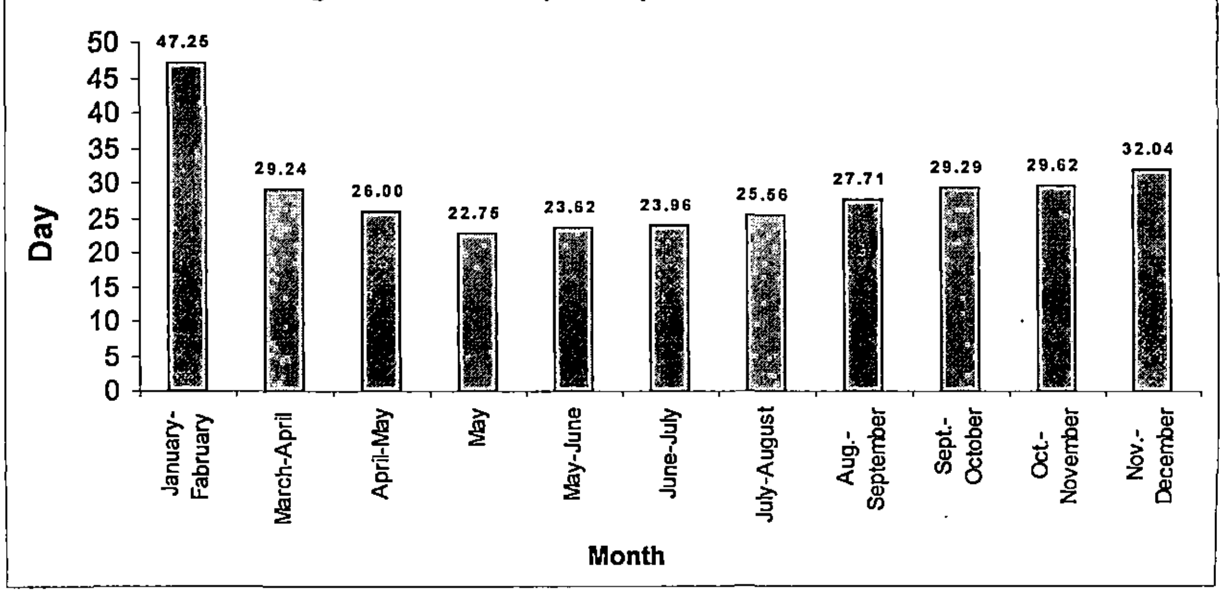


Fig. 9. Adult emergence of *C.chinensis*

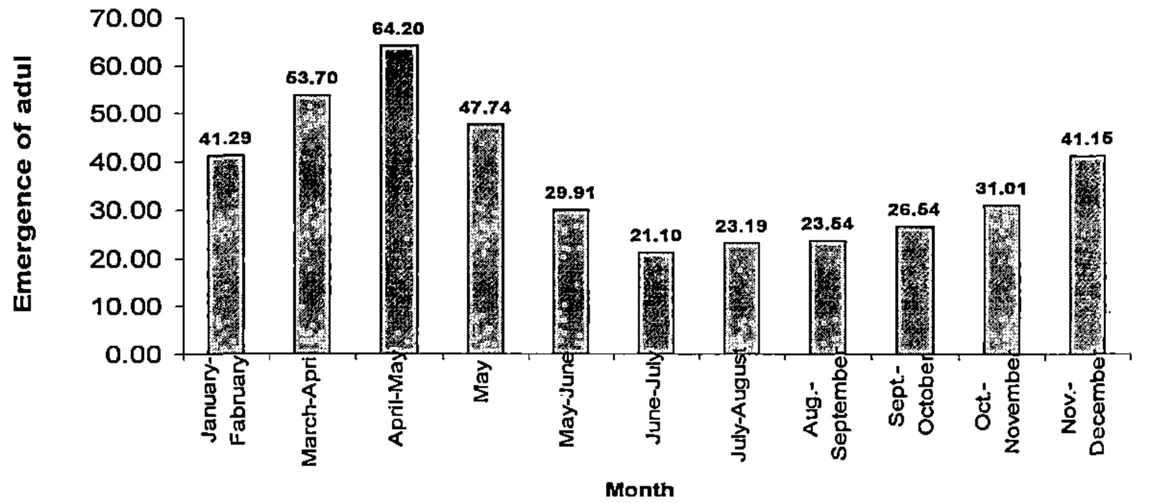
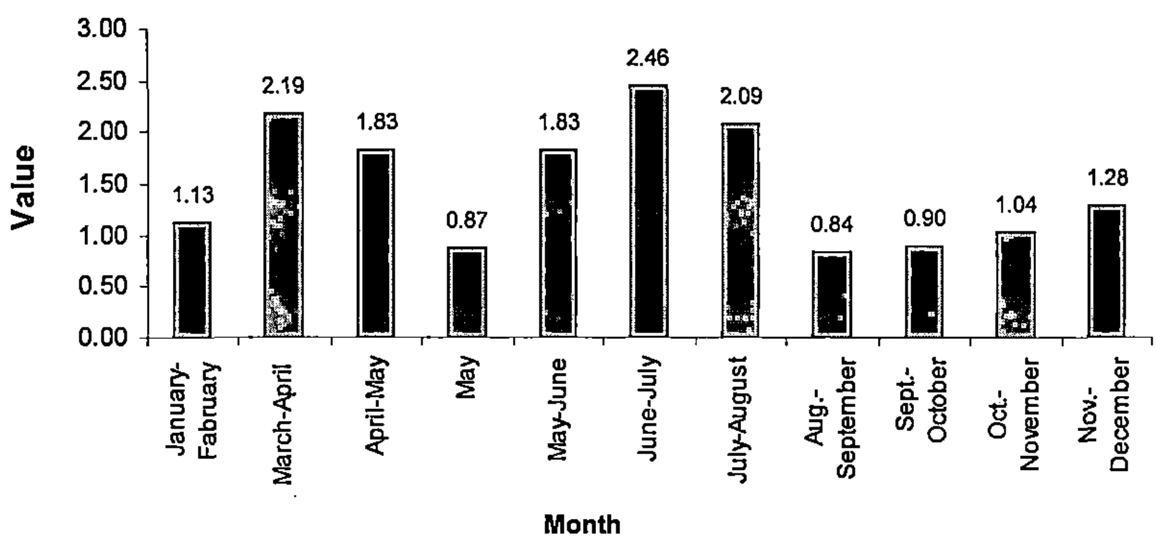


Fig.10 Growth Index (G.I.) of *C. chinensis*



4.2.10. Growth index (GI)

The growth index (Mean per cent adult emergence / mean development period) differ in different generations. The highest GI (2.19) and the lowest GI (0.52) were observed during March-April and August-September respectively. Growth Index value also recorded 0.71 during September-October followed by 0.73 (June-July) and 0.84 (November - December).

Association of biological characters of *C. chinensis* to the temperature and relative humidity of different months revealed that only the fecundity of *C. chinensis* was positively correlated with the laboratory temperature and relative humidity where fecundity with temperature showed highly significant value. Others biological parameters were negatively correlated. Growth Index (GI) of *C. chinensis* was non-significant with temperature and relative humidity (**Table 12** and **13**).

Table 11. Bio-ecology of *C. chinensis* : a laboratory study

(Average of 3 years, January 1999 to December 2001).
The values are means ±SD and ranges in parenthesis

Month	Oviposition period (day)	Fecundity (no)	Incubation period (day)	Hatching (%)	Larval-pupal period (day)
Jan.-Feb.	10.75 ± 1.25 (11-12)	79.00 ±10.16 (62-92)	10.75±1.61 (9-12)	67.70 ± 5.49 (60-79)	36.50 ± 1.75 (34-37)
Mar.-April	7.00 ± 0.81 (6-8)	93.81±7.31 (85-109)	4.75 ± 0.72 (4-6)	78.45 ± 6.13 (71-88)	24.50 ± 1.60 (23-26)
April-May	4.50 ± 0.57 (4-5)	88.50 ±5.73 (86-95)	3.75±0.65 (3-5)	66.75 ± 4.93 (63-74)	22.25 ± 1.38 (20-24)
May	4.25 ± 0.54 (4-5)	89.66 ±6.07 (81-97)	3.50 ±0.47 (3-4)	59.10 ± 5.98 (46-71)	19.46 ± 1.48 (17-22)
May-June	4.75 ± 0.57 (4-6)	85.20 ±6.23 (74-92)	4.25 ±0.52 (4-5)	51.88 4.96 (44-58)	19.27 ± 2.50 (16-21)
June-July	5.00 ± 0.84 (4-6)	95.62 ±3.85 (88-98)	4.50 ±0.47 (4-5)	42.15± 2.40 (39-46)	18.55 ± 1.74 (16-21)
July-Aug.	5.20 ± 0.90 (4-6)	93.22 ± 6.39 (86-106)	4.75 ± 0.21 (4-5)	39.27± 2.86 (36-44)	20.70 ± 2.49 (18-23)
Aug-Sept.	5.25 ± 0.95 (4-6)	75.37 ±7.17 (63-82)	5.25± 0.48 (5-6)	46.30 ± 4.42 (39-61)	23.57 ± 2.69 (19-25)
Sept.-Oct.	5.25 ± 0.50 (5-6)	68.81 ±5.36 (59-78)	5.50± 0.59 (5-6)	50.81 ± 5.45 (42-.59)	23.76 ± 2.85 (20-26)
Oct.-Nov.	6.25 ± 0.95 (5-7)	65.41 ±5.28 (57-75)	6.62 ± 0.51 (6-8)	51.27 ± 2.55 (44-61)	24.57 ± 2.54 (21-27)
Nov.-Dec.	7.50 ± 1.29 (6-9)	64.09 ±5.12 (59-74)	8.75 ± 1.31 (7-10)	49.60 ± 3.26 (45-59)	27.38 ± 2.66 (24-31)
SEm ±	**0.34**	**2.98**	**0.34**	**2.41**	**0.68**
CD at 5%	**0.74**	**6.44**	**0.79**	**5.28**	**1.47**

Table 11. Continued

Month	Adult emergence (%)	Developmental period (day)	Longevity of adult female (day)	Longevity of adult male (day)	Sex ratio (female: male)	Growth Index (GI)
Jan.- Febr.	41.29±2.16 (38-44)	47.25±3.21 (43-51)	12.00 ± 2.06 (11 –14)	14.10 ± 2.02 (12-17)	1:1.1	0.87
Mar.-Apr.	53.70±5.05 (47-59)	29.24± 2.19 (27-32)	7.55 ± 0.72 (7 –9)	9.70± 1.13 (8-11)	1:2.19	1.83
Apr.-May	64.20±3.09 (59-68)	26.00 ± 2.61 (23-28)	6.66 ± 0.50 (6 –7)	7.90± 0.73 (7-9)	1:1.83	2.46
May	47.74±4.71 (42-52)	22.75± 2.19 (19-24)	6.50 ± 0.53 (6 –7)	7.27 ± 1.27 (6-8)	1:1.99	2.09
May-June	29.91 ± 5.26 (23-36)	23.62± 1.79 (20-24)	6.40 ± 0.51 (6 – 7)	7.41 ± 2.51 (6-9)	1:1.26	1.26
June-July	21.10 ± 3.06 (18-24)	23.96± 2.01 (21-25)	7.36 ± 0.08 (7 –8)	8.18 ± 1.16 (7-9)	1:0.73	0.88
July-Aug.	23.19 ± 3.46 (20-26)	25.56 ± 2.64 (21-28)	7.79 ± 1.05 (6 – 8)	8.33 ± 1.00 (8-10)	1:1.13	0.90
Aug.-Sept.	23.54 ± 3.02 (20-27)	27.71 ± 3.52 (23-30)	7.87 ± 0.51 (7-9)	8.79 ± 0.77 (8-11)	1:0.52	0.84
Sept.-Oct.	26.54 ± 3.39 (23-29)	29.29 ± 2.02 (25-31)	7.92 ± 0.86 (7-9)	8.98 ± 0.78 (8-11)	1:0.73	0.90
Oct.-Nov.	31.01 ± 4.69 (34-38)	29.62 ± 2.71 (26-33)	8.54 ± 2.03 (7-10)	9.18 ± 1.08 (8-11)	1:1.38	1.04
Nov.-Dec.	41.15 ± 5.73 (36-47)	32.06 ±3.69 (28-36)	9.07 ± 1.08 (8-11)	11.79 ± 1.43 (10-13)	1:0.84	1.28
SEm.±	1.74	0.85	0.61	0.50	-	0.04
CD at 5%	3.76	1.84	1.09	1.08	-	0.09

Table 12. Temperature and relative humidity in the experimental laboratory
(Average of 3 years, Jan. 1999 – Dec. 2001)

Month	Mean daily temperature (°C)		Average daily temperature (°C)	Mean daily relative humidity (%)		Average daily relative humidity (%)
	Min	Max		Min	Max	
Jan. –Feb.	16.90	28.23	21.83	51.00	68.38	60.16
Mar. -April	23.97	30.55	27.25	52.11	68.91	59.67
April -May	26.47	31.02	29.02	62.75	78.96	69.80
May	27.68	31.92	29.65	69.50	78.96	74.57
May -June	27.36	31.60	29.19	69.59	84.64	78.16
June -July	26.36	30.25	28.73	73.25	84.92	80.76
July –Aug.	26.96	30.42	28.72	72.11	84.86	80.74
Aug.- Sept.	26.26	30.06	28.32	77.25	85.21	81.29
Sept.-Oct.	25.57	29.59	25.91	67.50	82.34	77.45
Oct.-Nov.	22.92	28.66	25.62	60.00	78.11	69.78
Nov.-Dec.	19.43	25.30	22.38	55.75	68.98	65.56

Table13. Association of biological characters of C. *chinensis* to the average of different months.

Biological parameters	Average Temperature °C	Average relative humidity (%)
Ovipositional period (d)	- 0.8977 (**)	- 0.7503 (**)
Fecundity (no.)	0.6007 (**)	0.1607
Incubation period (d)	- 0.9644 (**)	- 0.5757 (*)
Hatching (%)	- 0.204 0	- 0.8121 (**)
Larval-pupal period (d)	- 0.8592 (**)	- 0.7030 (**)
Adult emergence (%)	- 0.1689	- 0.8129 (**)
Developmental period (d)	- 0.8836 (**)	- 0.6536 (**)
Longevity of adult male (d)	- 0.8625 (**)	- 0.5989 (*)
Longevity of adult female (d)	- 0.8549 (**)	- 0.5077 (*)
Growth Index (G.I.)	- 0.2854	- 0.5003 (*)

(*) Significant at 5% level (**) Significant at 1% level

4.3. Studies on bio-ecology of C. *analis* on green gram in the laboratory.

These observations (**Table 14**) were taken from twelve sets of observations in each month of the year at different temperatures and relative humidity on monthly basis (**Table 15**.).

4.3.1. Ovipositional period

It was observed that ovipositional period differed in different generations. The mean longest period of 11.25 days was recorded during January -February and the shortest period was 5.2 days recorded during May-June. The range of ovipositional period was relatively long during November - March (ranged, 8 to 14 days) where the temperature and relative humidity (%) were relatively lower than the other months. During the period from April - October the span of oviposition was short, the range was being 5 to 7 days.

4.3.2. Incubation period

The longest incubation period was during January - February (10-12 days), followed by during November - January (9-11 days) and Feb.-March (8-10 days). During the warm months the incubation period was relatively short. The shortest period recorded 5.31 ±0.78 days during the month of May - July.

4.3.3. Larval - pupal duration

It was the longest during November – January (50 to 53 days) with a mean of 51.51 days which was almost three times longer than the minimum duration of 17-20 days with a mean of 19.16 days recorded during June-July. The duration exhibited a trend similar to that of incubation period.

4.3.4. Total development period

The developmental period of C. analis took as long as 59-63 days during January – February, followed by November – January and February – March. The shortest period recorded durimg May – September (21 to 25 days).

4.3.5. Longevity of adults

The females had a shorter life span in comparison to that of the males. Males of January - February generation survived for 12 to 16 days whereas females survived for 11 to 14 days. Minimum longevity of both males and females were recorded 5 to 6 days respectively during May - June.

4.3.6. Sex ratio

Sex ratio (female: male) differed in different generations. Males out-numbered the females in all the generations during November - July. But the females out-numbered the males during July-November. The highest proportion of males (female: male = 1:1.5) was obtained during January -February and the lowest proportion during September – October (female: male = 1:0.8).

4.3.7 Fecundity

Fecundity had considerable differences in different generations (**Table 14**)The descending order of fecundity was April (105-109), March-April (95-101), June-July (96-99), May-June (93-98),August - September (92-96), July - August (83-87), September - October (74-78), November - January (55-63), October – November (51-62), February - March (33-37) and the lowest fecundity was of 21 to 24 eggs obtained during January - February (21 to 24).

4.3.8. Hatchability

Percentage of hatching of eggs also differed considerably in different months. More than fifty per cent hatching occurred during winter and summer (Nov. to April). It declined significantly from May onwards and up to Oct.-Nov. and lowest hatchability of 25 to 29 % was observed during July.

4.3.9. Adult emergence

Adult emergence percentage were March-April (59 to 60%), Feb.- Mar. (54 to 60%), Oct.- Nov. (51 to 54%), Sept.- Oct.(37 to 40%) and May - June (32 to 36%). It was lower (below 25%) during the month of Nov.-Jan.(19-21%), Aug.-Sept.(19-22%), June-July (19-23%) and the lowest per cent of adult emergence was recorded in the generation during Jan.-Feb. (6-10% only).

4.3.10. Growth Index (GI)

In case of growth index (mean percent of adult emergence / mean development period), the highest value (**Table 14**) above the level of 1.00 was obtained during March-April (1.98 ± 0.02) followed by April (1.78 ± 0.04), Oct.-Nov. (1.72 ± 0.06) and May-June (1.45 ± 0.40). The minimum GI value was recorded during Jan.-Feb. (0.14 ± 0.01), Nov.-Jan. (0.33 ± 0.01), July-Aug. (0.46 ± 0.05), Aug.-Sept. (0.84 ± 0.06), June-July (0.96 ± 0.05).

The association of the above biological characters to the laboratory temperature and relative humidity showed mostly significant and negative value. Only the fecundity was positively correlated but non-significant (**Table 15** and **16**).

Table 14. Temperature and relative humidity in the laboratory during the study of bio -ecology of C. *analis*

(Average of 3 years, July 1999 – July 2001)

Month	Mean daily temperature (0C)		Average daily temperature (0C)	Mean daily relative humidity (%)		Average daily relative humidity (%)
	Min	Max		Min	Max	
July	27.57	30.09	28.98	78.85	83.28	77.77
July to Aug.	28.56	30.09	28.78	79.25	81.72	80.74
Aug. to Sept.	27.92	28.72	28.32	77.29	80.87	80.29
Sept. to Oct.	27.32	28.27	27.51	65.58	74.04	69.78
Oct. to Nov.	24.13	27.11	25.62	65.53	74.04	69.78
Nov. to Jan.	20.63	24.13	22.38	60.00	65.59	65.56
Jan. to Feb.	17.82	22.19	19.69	51.00	62.21	61.84
Feb. to Mar.	19.69	27.03	23.53	55.31	63.23	57.27
Mar. to Apr.	26.12	28.39	27.25	54.31	65.03	59.67
April	27.32	29.10	28.39	62.75	68.91	65.50
May to June	28.73	29.65	29.19	74.57	81.76	78.16
June to July	27.50	30.13	28.73	79.77	81.76	80.73

Fig.11. Oviposition period of *C.analis*

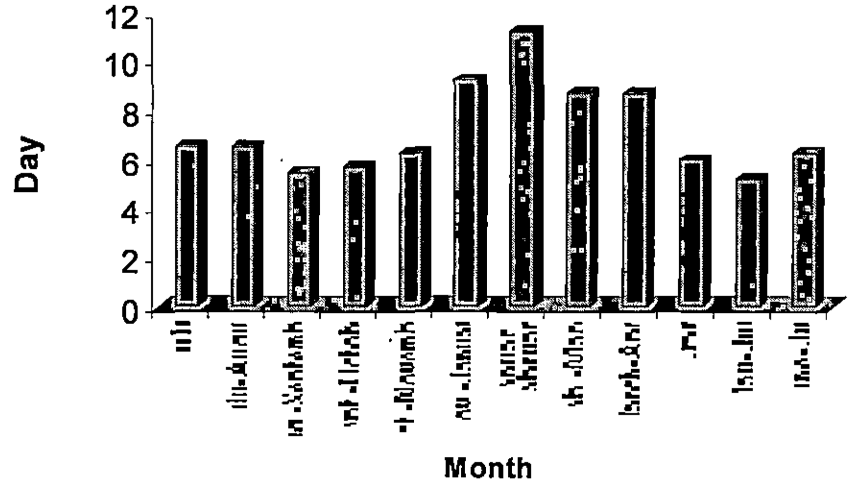


Fig.12. Fecundity of *C.analis*

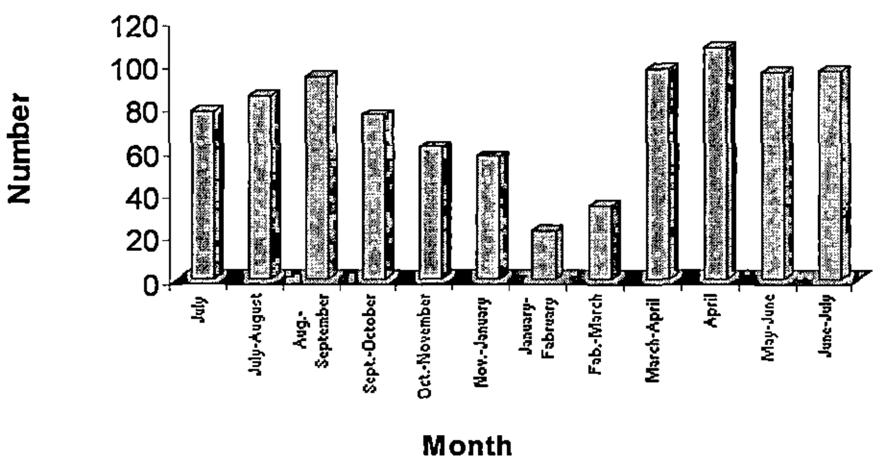


Fig.13. Incubation period of *C.analis*

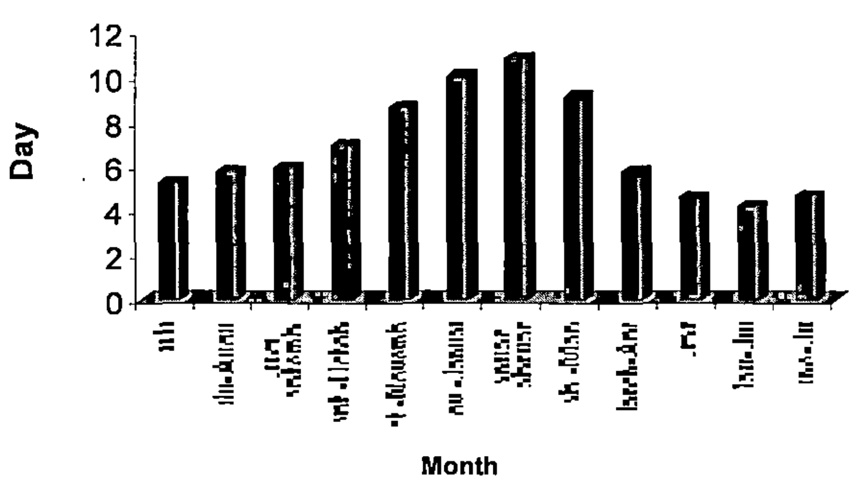


Fig. 14. Hatchability of *C.analis*

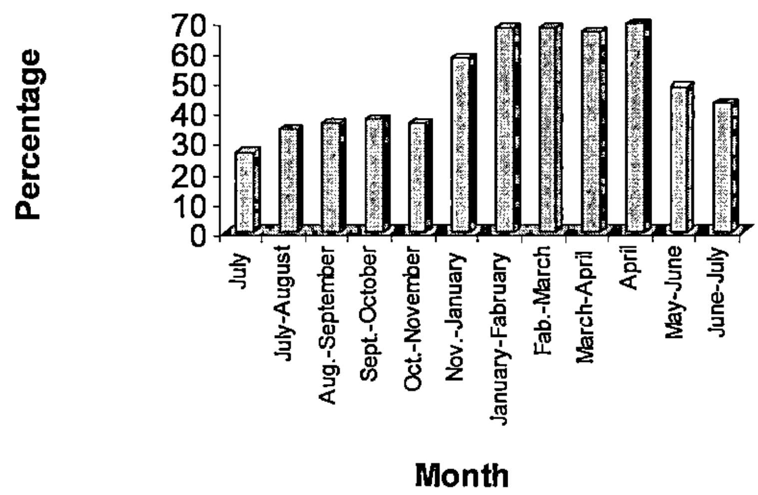


Fig. 15. Larval-pupal period of *C.analis*

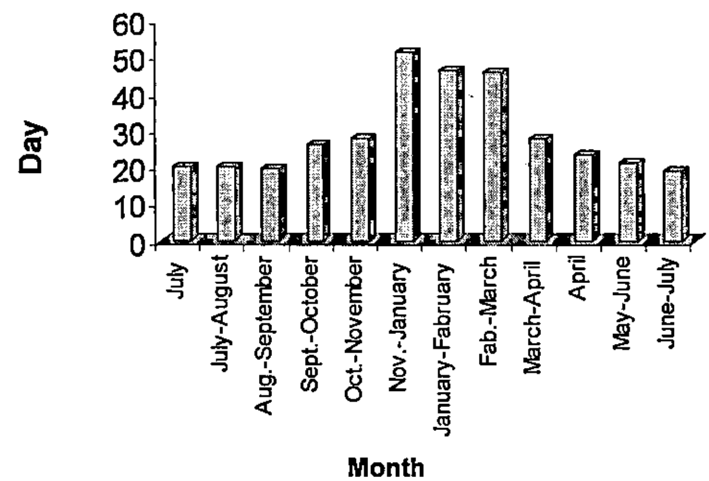


Fig. 16. Developmental period of C.analis

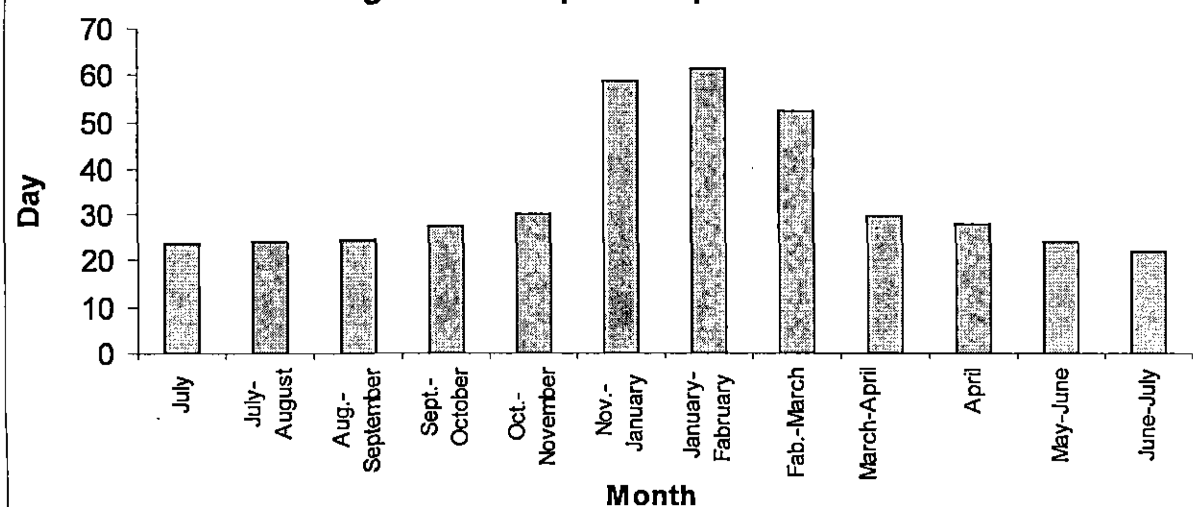


Fig. 17. Adult emergence of *C.analis*

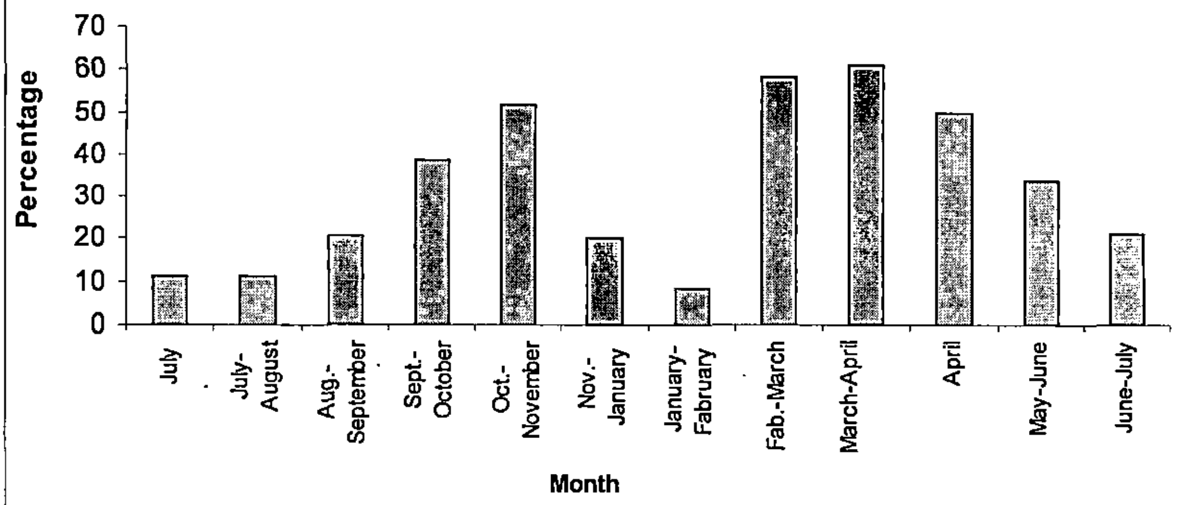
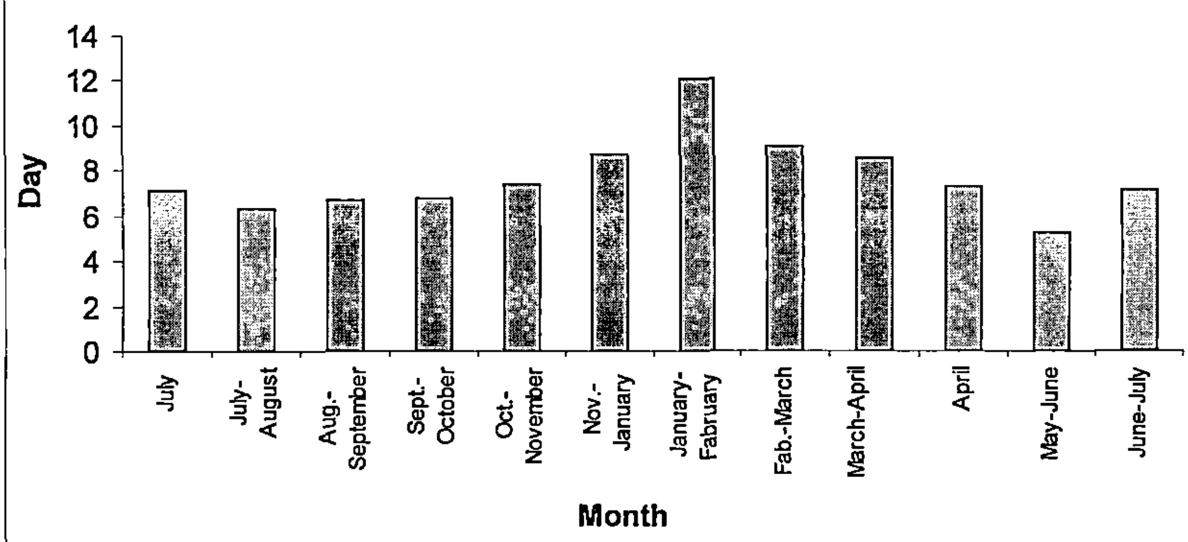


Fig. 18. Longevity of adult female



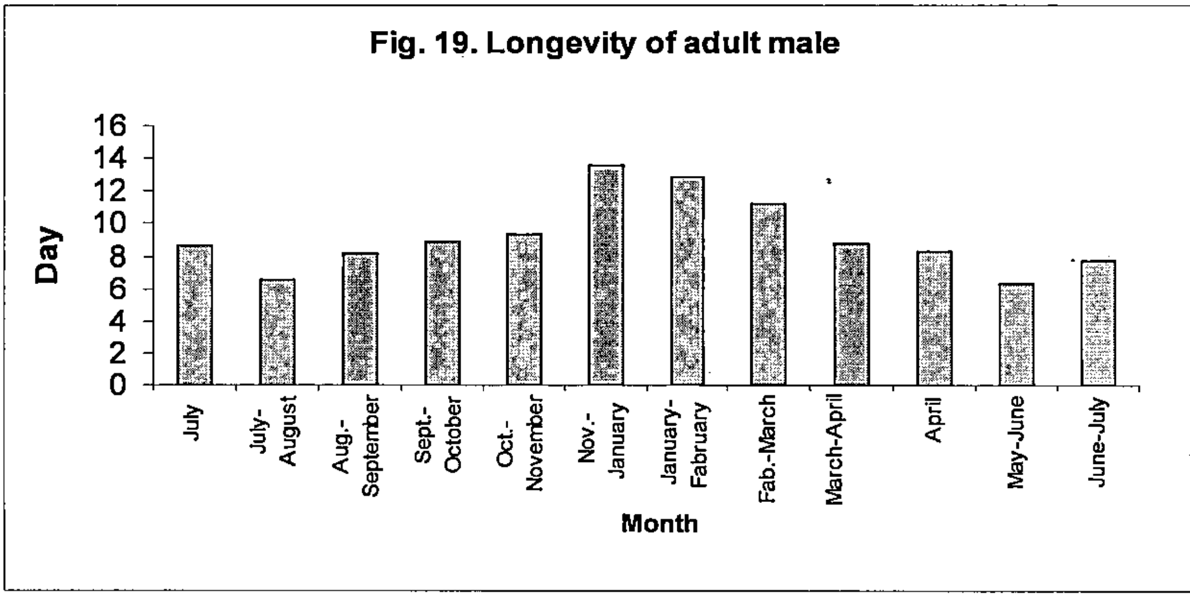


Fig. 19. Longevity of adult male
Day
0
2
4
6
8
10
12
14
16
July
July-August
Aug.-September
Sept.-October
Oct.-November
Nov.-January
January-Fabruary
Fab.-March
March-April
April
May-June
June-July
Month

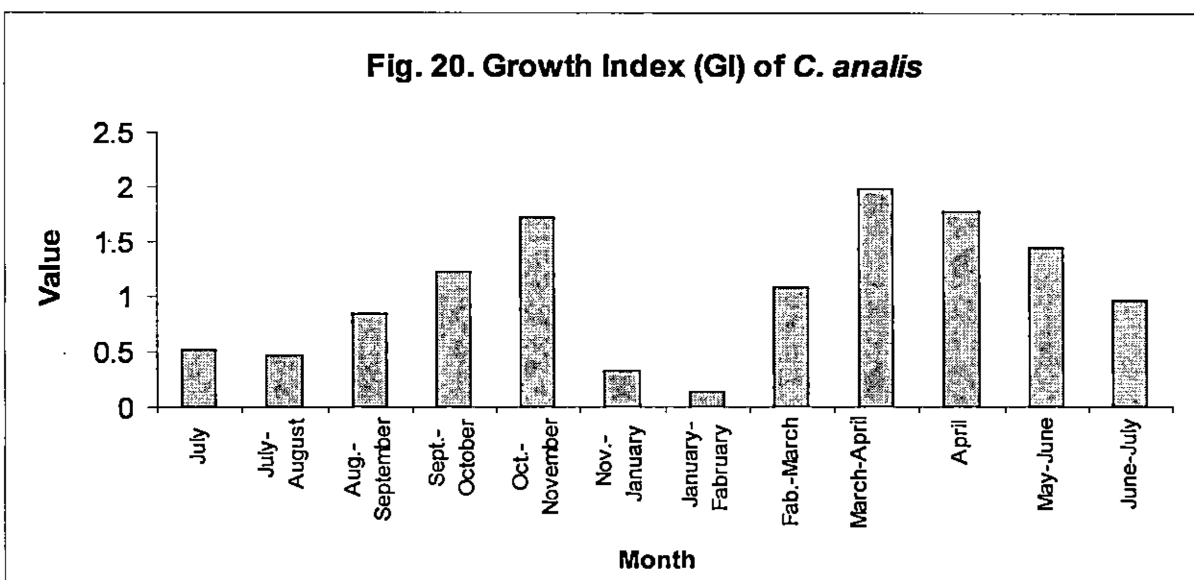


Fig. 20. Growth Index (GI) of C. analis
Value
0
0.5
1
1.5
2
2.5
July
July-August
Aug.-September
Sept.-October
Oct.-November
Nov.-January
January-Fabruary
Fab.-March
March-April
April
May-June
June-July
Month

Table 15. Bio-ecology of *C. analis* : a laboratory study

(Average of 3 years, July 1999 – July 2001). The data are mean ±S.D. and ranges

Month	Ovipositional period (day)	Fecundity/female (no)	Incubation period (day)	Hatching (%)	Larval-pupal period (day)
July	6.50±0.57 (6-7)	78.25±1.71 (76-80)	5.31±0.78 (4-5)	26.75±1.70 (25-29)	20.12±0.82 (19-21)
July -Aug.	6.50±0.54 (6-7)	85.25 ± 1.70 (83-87)	5.81±0.62 (4-6)	34.25±1.62 (32-35)	20.29±0.94 (19-21)
Aug.-Sept.	5.50±0.58 (5-6)	94.25 ± 1.70 (92-96)	5.97±0.31 (5-6)	36.50±1.29 (35-38)	19.61±1.21 (18-21)
Sept.- Oct.	5.75±0.95 (5-6)	77.00 ± 2.16 (74-78)	6.96±0.52 (5-7)	37.75±1.39 (36-40)	26.27±1.72 (24-28)
Oct.- Nov.	6.25±0.91 (5-7)	61.84 ±1.86 (51-62)	8.61±0.41 (7-9)	36.25±1.52 (34-38)	27.92±0.99 (27-29)
Nov.- Jan.	9.25±0.95 (8-10)	57.27±2.20 (55-63)	10.02±0.68 (9-11)	58.00±1.82 (56-60)	51.51±1.20 (50-53)
Jan.- Feb.	11.25 ± 1.75 (09-14)	22.75 ± 1.25 (21-24)	10.81±1.32 (10-12)	67.75±3.20 (66-71)	46.52±1.27 (45-48)
Feb.- March	8.75 ± 0.95 (8-12)	34.75 ± 1.70 (33-37)	9.10±0.91 (8-10)	67.80±3.76 (68-73)	46.00±2.12 (44-49)
Mar.- April	8.75 ± 1.25 (7-10)	98.5 ± 3.00 (95-101)	5.82±0.97 (5-7)	66.50±3.00 (64-68)	27.75±0.59 (23-24)
April	6.00 ± 0.81 (5-7)	107.75 ± 1.89 (105-109)	4.62±0.79 (4-5)	69.25±1.89 (68-72)	23.28±0.61 (23-24)
May to June	5.25± 0.57 (4-6)	96.00 ± 2.16 (93-98)	4.21±0.58 (3-5)	48.50±1.29 (47-50)	21.21±0.82 (20-22)
June to July	6.25±1.59 (6-7)	97.5 ± 1.29 (96-99)	4.69±0.72 (3-5)	43.00±1.82 (41-45)	19.16±1.41 (17-20)
SEm ±	**0.46**	**2.37**	**0.29**	**1.16**	**0.56**
C.D. at 5%	**0.96**	**4.69**	**0.61**	**2.42**	**1.18**

Table 15. Continued.

Month	Adult Emergence (%)	Developmental period (day)	Longevity of adult female (day)	Longevity of adult male (day)	Sex ratio (female: male)	Growth Index (GI)
July	11.50±01.29 (10-13)	23.75±0.98 (23-25)	7.16±0.46 (6-8)	8.66±0.81 (8-10)	1:1.1	0.51
July -Aug.	11.25±0.23 (9-13)	24.25±0.50 (24-25)	6.31±1.01 (5-7)	6.59±0.71 (6-7)	1:0.9	0.46
Aug.-Sept.	20.50±1.29 (19-22)	24.29±0.95 (23-25)	6.68±0.54 (6-7)	8.12±0.82 (7-9)	1:0.9	0.84
Sept.- Oct.	38.50±1.21 (37-40)	27.50±1.29 (26-29)	6.76±0.72 (6-7)	8.82±0.52 (8-9)	1:0.8	1.23
Oct.-Nov.	51.75±1.68 (51-54)	30.20±0.87 (29-31)	7.39±0.87 (7-8)	9.39±0.62 (9-10)	1:0.9	1.72
Nov.- Jan.	20.00±0.81 (19-21)	58.72±0.87 (58-60)	8.72±0.94 (8-10)	13.58±1.77 (11-16)	1:1.2	0.33
Jan.- Feb.	8.33±1.86 (6-10)	61.5±1.73 (59-63)	12.14±1.46 (11-14)	12.85±1.77 (12-16)	1:1.5	0.14
Feb.- Mar.	58.25±1.62 (54-60)	52.25±1.68 (50-54)	9.14±1.06 (8-10)	11.25±1.25 (10-13)	1:1.4	1.09
Mar.-April	61.25±1.59 (59-63)	29.50±1.29 (28-31)	8.60±1.14 (7-9)	8.79±1.28 (7-10)	1:1.2	1.98
April	49.75±1.42 (48-52)	28.00±0.89 (27-29)	7.32±0.84 (6-8)	8.26±1.11 (8-10)	1:1.1	1.78
May -June	33.75±1.64 (32-36)	24.25±0.97 (23-25)	5.29±0.58 (5-6)	6.36±0.98 (5-7)	1:1.3	1.45
June-July	21.00±1.82 (19-23)	22.00±0.85 (21-23)	7.12±0.72 (6-8)	7.69±0.95 (7-9)	1:1.2	0.96
SEm ±	**0.87**	**0.53**	**0.36**	**0.56**	-	**0.03**
C.D. at 5%	**1.82**	**1.18**	**0.75**	**1.14**	-	**0.07**

Table 16. Association of biological parameters of *C. analis* to the average temperature and average r. h. of different months.

Biological parameters	Average Tem. ^{0}C	Average r. h. (%)
Ovopositional period (d)	- 0.8751 (**)	- 0.6943 (**)
Fecundity (no.)	0.2331	0.3703
Incubation period (d)	- 0.8585 (**)	- 0.4921
Hatching (%)	- 0.5551(*)	- 0.8199 (**)
Larval-pupal period (d)	- 0.9384 (**)	- 0.7478 (**)
Adult emergence (%)	- 0.0605	- 0.5843 (*)
Developmental period (d)	- 0.9663 (**)	- 0.7019 (**)
Longevity of adult male (d)	- 0.9322 (**)	- 0.6882 (**)
Longevity of adult female (d)	- 0.8239 (**)	- 0.7204 (**)
Growth index (GI)	- 0.4143	- 0.2281

(*) Significant at 5% level
(**) Significant at 1% level

4.4. Relative preference and susceptibility of *C. chinensis* and *C. analis* to fourteen species of stored pulses during summer and winter by CHOICE TEST

4.4.1. Ovipositional preference by free choice test

This test was carried out during summer with 0-1 day old 10 pairs of *C. chinensis* (10 male and 10 female). The average number of eggs laid by each female was considered. There were differences in ovipositional preference of both the species to different species of stored pulses *C. chinensis* laid the highest number of 13 eggs on red gram followed by green gram (11.3), moth bean (7.3), pea (7.0), soybean (6.3), small pea (6.3), black gram (5.6), thakri kalai (5.3), cow pea (5.3), kidney bean (4.6), lentil (4.3), grass pea (4.0), Bengal gram (3.6) and horse gram (1.3). *C. analis* showed a similar pattern of ovipositional preference with few exceptions. Here, less preferred pulses were lentil (1.3), horse gram (1.3) and kidney bean (2.3) during summer whereas higher numbers of eggs were laid on green gram (09.3), black gram (9.5), pea (9.0), small pea (9.0) and cow pea (8.0). On rest of the pulses, the number of eggs laid/female was 3 to 5 only (Table 17).

During winter, *C. chinensis* preferred to lay maximum number of eggs on red gram (9.3), followed by on green gram (7.6), lentil (6.6), small pea (6.6), soybean (5.0), pea (4.6), moth bean (4.3), grass pea (3.6) and black gram (3.6). Less preferred pulses were kidney bean (2.0), Bengal gram (2.3), horse gram (2.6), thakri kalai (3.3) and cowpea (3.0). In this respect there was significant differences between the two species of *Callosobruchus*. *C. analis* had a maximum choice for black gram (12.0), red gram (10.0) followed by thakri kalai (9.6), cow pea (8.0), grass pea (7.6), green gram (7.0), soybean (7.0) and small pea (6.0). Less preferred pulses were lentil (1.3), kidney bean (1.6), horse gram (1.6), pea (2.6), chick pea (3.6) and moth bean (3.6) (**Table 17**).

4.4.2. Emergence of adult by free choice test

Mean percentage of adult emergence of both the species differed considerably during summer *C. chinensis* emerged in higher number from red gram (70 %), green gram (63 %), cow pea (59.3%), moth bean (57.3 %), lentil (50.6 %), Bengal gram (44.7%), grass pea (40.3 %), pea (29.0%) and horse gram (14.6%). A very low percentage of adult emergence took place from black gram (5.6 %) and thakri kalai (3.0 %). Adults could not emerged at all from soybean, kidney bean and small pea (**Table 18**).

C. analis emerged in highest number from green gram (27.3 %) followed by thakri kalai (19.3%), red gram (19.6%), black gram (17.3%), cow pea (16.0 %) chick pea (13.7%), moth bean (8.6%), grass pea (8.0%), horse gram (7.3%) and pea (4.6%). Adults could not emerge at all from lentil, soybean, kidney bean and small pea during summer (**Table 18**).

The percentage of adult emergence from different pulses did not differ much during winter in comparison to that during summer. In general the emergence was low during winter. *C. chinensis* emerged in highest percentage from green gram (58.3%) followed by red gram (53.3%), moth bean (51.6%), lentil (50.3%), cow pea (47.3%), Bengal gram (40.0%), grass pea (33.6%), pea (17.6%), horse gram (14.6%). No adult emergence occurred from black gram, thakri kalai, soybean, kidney bean and small pea during summer (**Table 18.**). But in case of *C. analis* the values were 25.6 %, 19.3 %), 16.0 %, 7.3 %, pea 6.0 %, 5.3 %, 5.3 %, 5.0 % and 3.3 % from cow pea, green gram, red gram, chick pea, black gram, thakri kalai, grass pea and horse gram respectively. In spite of egg lay there was no emergence of *C. analis* from lentil, moth bean, soybean, kidney bean and small pea (**Table 18**).

Table 17. Ovipositional preference of *C. chinensis* and *C. analis* on fourteen species of stored pulses by FREE CHOICE TEST

(Average of 3 seasons, 1999 -2001)

PULSE	Mean umber of eggs laid / female			
	SUMMER		WINTER	
	C. chinensis	*C. analis*	*C. chinensis*	*C. analis*
Green gram **(*Vigna radiata*)**	11.3	09.3	07.6	07.0
Grass pea **(*Lathyrus sativus*)**	04.0	04.6	03.6	07.6
Cow pea **(*V. catiang*)**	05.3	08.0	03.0	08.0
Red gram **(*Cajanus cajon*)**	13.0	06.5	09.3	10.0
Bengal gram **(*Cicer areitinum*)**	03.6	03.3	02.3	03.6
Pea **(*Pisum sativum*)**	07.0	09.0	04.6	02.6
Lentil **(*Lens esculentum*)**	04.3	01.3	06.6	01.3
Black gram **(*V. mungo*)**	05.6	09.5	03.6	12.0
Horse gram **(*Dolicos biflorus*)**	01.3	01.3	02.6	01.6
Moth bean **(*V. aconitifolia*)**	07.3	05.0	04.3	03.6
Soybean **(*Glycine max*)**	06.3	07.0	05.0	07.0
Kidney bean **(*Phaseolus vulgaris*)**	04.6	02.3	02.0	01.6
Thakri kalai **(*V.mungo silvestries*)**	05.3	06.3	03.3	09.6
Small pea **(*P. arvense*)**	06.3	09.0	06.6	06.0
SEm.±	**0.47**	**0.52**	**0.41**	**0.74**
C.D. at 5%	**0.94**	**1.03**	**0.82**	**1.46**

Figures in the tables are mean number of eggs laid / female

Table 18. Mean adult emergence (%) of C. *chinensis* and C. *analis* from fourteen species of stored pulses by FREE CHOICE TEST

(Average of 3 seasons, 1999-2001)
The Figures in parenthesis are angular transformed values

Pulses	Adult emergence (%) / female			
	SUMMER		WINTER	
	C. chinensis	*C. analis*	*C. chinensis*	*C. analis*
Green gram (*Vigna radiata*)	63.3 (52.7)	27.3 (31.4)	58.3 (49.7)	19.3 (26.0)
Grass pea (*Lathyrus sativus*)	40.3 (39.4)	08.0 (16.4)	33.6 (35.4)	5.0 (12.9)
Cow pea (*Vigna catiang*)	59.3 (50.3)	16.0 (23.5)	47.3 (43.4)	25.6 (30.3)
Red gram (*Cajanus cajon*)	70.0 (56.7)	19.6 (26.2)	53.3 (46.8)	16.0 (23.5)
Bengal gram (*Cicer areitinum*)	44.3 (41.7)	13.7 (24.8)	40.0 (39.2)	07.3 (15.6)
Pea (*Pisum sativum*)	29.0 (32.5)	04.6 (12.3)	17.6 (24.8)	06.0 (14.1)
Lentil (*Lens esculentum*)	50.6 (45.3)	0.0 (0.0)	50.3 (45.1)	0.0 (0.0)
Black gram or Urd (*Vigna mungo*)	5.6 (13.6)	17.3 (24.5)	0.0 (0.0)	5.3 (13.3)
Horse gram (*Dolicos biflorus*)	14.6 (22.4)	7.3 (15.6)	14.6 (22.4)	3.3 (10.4)
Moth bean (*Vigna aconitifolia*)	57.3 (49.1)	8.6 (17.0)	51.6 (45.9)	0.0 (0.0)
Soybean (*Glycine max*)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Kidney bean (*Phaseolus vulgaris*)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Thakri kalai (*Vigna mungo silvestries*)	3.0 (9.9)	19.3 (26.0)	0.0 (0.0)	05.30 (13.30)
Small pea (*Pisum arvense)*	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
SEm ±	**1.26**	**0.98**	**1.26**	**0.91**
C.D. at 5%	**2.50**	**1.95**	**2.50**	**1.49**

4.4.3. Ovipositional preference by no choice test

The study was undertaken on of fourteen different species of pulses during both summer and winter seasons (**Table 19**). The values differed in the two species of *Callosobruchus* .During summer, both the laid eggs differently on of different pulses. Mean number of eggs laid by a female *C. chinensis* on green gram were the highest (99.3) followed by Bengal gram (93.0), cow pea (87.0), grass pea (81.6), thakri kalai (*V. mungo silvestris*) (78.0), black gram (*V. mungo*) (77.3), lentil (72.3), pea (72.0), moth bean (70.0), red gram (69.0) and horse gram (67.3), whereas less preferred pulses were kidney bean (33.0), small pea (50.6) ad soybean (59.6). On the other hand *C. analis* deposited maximum of 88.6 eggs on black gram followed by green gram (86.3), cow pea (82.6), red gram (82.0), moth bean (75.3), Bengal gram (74.3), horse gram (74.0), pea (72.6) and soybean (71.6).The less preferred pulses were kidney bean (49.3) and small pea (65.3).

During winter *C. chinensis* laid much more number of eggs on different pulses than *C. analis*. The pattern of egg laying preference for the pulses was somewhat similar in the two species. However, *C. chinensis* preferred green gram the most and *C. analis* preferred black gram the most. Less preferred hosts of both the species were kidney bean , small pea , horse gram and soybean although *C. analis* didn't prefer lentil. In addition to the eggs laid on the surface of pulses, both the species laid quite a good number of eggs on the wall of test tubes (**Table 19**).

4.4.4. Adult emergence by no-choice test

The highest per cent of *C. chinensis* adults emerged from lentil (71.0) followed by red gram (67.3), green gram (63.3), grass pea (61.1), moth bean (57.0), cow pea (53.3), horse gram (49.0), chick pea (36.8) and pea (33.3). Only 6 % adult emerged from black gram seeds. In case of *C. analis* the mean percentage of adult emergence also differed in different pulses, although the percentage of damage was comparatively less than that of *C. chinensis*. The highest emergence took place from red gram (65.3%) and the lowest was from thakri kalai (16.3%). Interestingly, there was no adult emergence in case of of both the species from soybean, kidney bean and small pea (**Table 20**).

Percentage damage by both the species has shown significant differences during winter (**Table 20**). In case of *C.chinensis* 66.1% adult emergence took place from lentil which was followed by grass pea (60.8%), green gram (54.6%), moth bean (51.6%), horse gram (50.9%), red gram (47.0%), cow pea (45.3%), Bengal gram (36.0%), pea (24.6%), thakri kalai (3.6%) and black gram (0.6%). With regard to *C. analis*, the percentage of adult emergence recorded was in the descending order of grass pea (27.9) > cow pea (27.2) > red gram (26.1) > green gram (23.5) > moth bean (22.2) > chick pea (20.7) > thakri kalai (18.7) > black gram (16.1) > horse gram (15.3) > pea (13.7). During the two seasons, both the beetles couldn't develop on small pea, kidney bean and soybean. It was revealed that lentil was less susceptible to the attack of *C. analis* during winter

Table 19. Ovipositional preference of C. *chinensis and* C. *analis* by NO CHOICE TEST

(Average of three seasons, 1999-2001)

Pulses	Mean ovipositional preference / female (in no.)			
	SUMMER		WINTER	
	C. chinensis	*C. analis*	*C. chinensis*	*C. analis*
Green gram (*Vigna radiata*)	99.3	86.6	78.6	55.6
Grass pea (*Lathyrus sativus*)	81.6	81.0	61.6	60.3
Cow pea or Lobia (*Vigna catiang*)	87.0	82.6	46.0	66.0
Red gram (*Cajanus cajon*)	69.0	82.0	50.3	59.0
Chick pea (*Cicer areitinum*)	93.0	74.3	65.6	58.3
Pea (*Pisum sativum*)	72.0	72.6	64.0	62.0
Lentil (*Lens esculentum*)	72.3	65.3	66.6	51.3
Black gram (*Vigna mungo*)	77.3	88.6	63.6	72.0
Horse gram (*Dolicos biflorus)*	67.3	74.0	57.3	58.0
Moth bean (*Vigna aconitifolia*)	70.0	75.3	66.6	64.0
Soybean (*Glycine max*)	59.6	71.6	64.4	64.0
Kidney bean (*Phaseolus vulgaris*)	33.0	49.3	46.6	46.0
Thakri kalai (*Vigna mungo silvestries*)	78.0	92.0	63.0	66.0
Small pea (*Pisum arvense*)	50.6	65.3	57.6	49.3
SEm ±	**1.14**	**0.95**	**1.13**	**0.74**
C.D. at 5%	**2.95**	**1.89**	**2.24**	**1.46**

Table 20. Per cent adult emergence of *C. chinensis* and *C. analis* by <u>no-choice test</u>

(average of 3 seasons,1999-2001)

Pulses	Mean per cent adult emerge / female			
	SUMMER		WINTER	
	C. chinensis	*C. analis*	*C. chinensis*	*C. analis*
Green gram (*Vigna radiata*)	63.3 (53.1)	44.1 (41.6)	54.6 (45.5)	23.5 (29.0)
Grass pea (*Lathyrus sativus*)	61.1 (51.4)	44.4 (41.7)	60.8 (51.1)	27.9 (31.6)
Cow pea or Lobia (*V. catiang*)	53.3 (46.8)	51.6 (45.9)	45.3 (42.3)	27.2 (31.4)
Red gram (*Cajanus cajon*)	67.3 (55.1)	65.3 (53.9)	47.0 (43.2)	26.1 (30.7)
Bengal gram (*Cicer areitinum*)	36.8 (37.3)	40.0 (39.2)	36.0 (36.8)	20.7 (27.0)
Pea (*Pisum sativum*)	33.3 (35.2)	30.5 (34.1)	24.6 (29.7)	13.7 (21.7)
Lentil (*Lens esculentum*)	71.0 (57.0)	18.3 (25.3)	66.1 (54.3)	6.0 (14.1)
Black gram or Urd (*V. mungo*)	6.0 (14.1)	26.6 (31.0)	0.6 (14.1)	16.1 (23.6)
Horse gram (*Dolicos biflorus*)	49.0 (44.4)	19.1 (25.9)	50.9 (45.5)	15.3 (23.0)
Moth bean (*Vigna aconitifolia*)	57.0 (49.0)	30.8 (33.7)	51.6 (45.9)	22.2 (28.0)
Soybean (*Glycine max*)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Kidney bean (*Phaseolus vulgaris*)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Thakri kalai (*V. mungo silvestries*)	6.8 (15.1)	16.3 (23.8)	3.6 (10.9)	18.7 (25.6)
Small pea (*Pisum arvense*)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
SEm ±	**1.20**	**1.14**	**1.28**	**0.99**
C.D. at 5%	**2.38**	**2.26**	**2.54**	**1.96**

Figures in parenthesis are the angular transformed values

4.4.5. Effect of physical characters, moisture contents and phenol contents of stored pulses on the oviposition, adult emergence and developmental period of both *C. chinensis* and *C. analis*

<u>Physical characters:</u>

Fourteen different kinds of stored pulses were studied group wise for their physical characters such as single seed weight, thickness of seed coat, moisture and also for phenol contents (**Table 24**). Interaction of the physio - chemical characters on the degree of infestation by assessing the number of eggs laid/female, emergence of adults/female and developmental period of both the species were studied during summer.

The seed color, shape and texture (**Table 4**) had no relation to the oviposition of eggs, emergence of adults and their development. Only kidney bean (*Phaseolus vulgaris*) having tan-brown color and small pea (*Pisum arvense*) having grayish mosaic color with rough texture affected oviposition of both the *C. chinensis* and *C. analis.*

The seed weights had significant negative correlation with the oviposition of *C. chinensis* where as *C. analis* had a significant positive correlation. Mean adult emergence of both the species showed a non-significant negative correlation. Mean developmental period was also negatively significant at 0.01% level (**Table 26**).

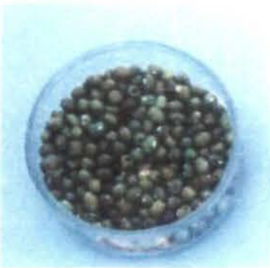
The thickness of seed coat differed significantly among the pulses. The thickness of seed was in the order of kidney bean (0.164mm) > bengal gram (0.138mm) > small pea (0.109mm)> cow pea (0.106mm) > grass pea (0.104mm) > thakri kalai (0.097mm) > horse gram (0.092mm) > black gram (0.091mm) > red gram (0.082mm) > pea (0.081mm) > green gram (0.078mm), moth bean (0.064) and lentil (0.048). This character showed a negative correlation with oviposition, adult emergence and developmental period of both *C. chinensis* and *C. analis* (**Table 26**).

The moisture content different pulses also differed significantly. The highest and the lowest moisture contents were on kidney bean (7.76%) and horse gram (5.09%) respectively. Among the rest of the pulses, the moisture (%) ranged in between 5 – 7 %. The seed moisture (%) had a non-significant negative correlation with egg laying, emergence of adult and developmental period of *C. chinensis* and *C. analis* (**Table 24** and **26**).

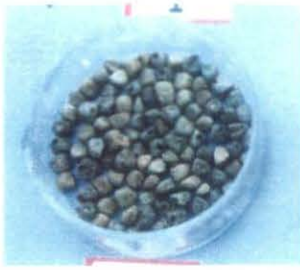
<u>Phenol contents and their impact:</u>

The phenol contents were in the order of kidney bean (1.43 milligram) > soybean (1.32mg) > pea (0.92mg) > small pea (0.87mg) > horse gram (0.79mg) > black gram (0.74mg) > chick pea (0.70mg) > thakri kalai (0.68mg) > cowpea (0.67mg) > lentil (0.64mg) > moth bean (0.62mg) > red gram (0.54mg) > green gram (0.48mg) > and grass pea (0.31mg). The differences were signify=cant (**Table 24**). The phenol contents were inversely proportional to the oviposition, adult emergence and developmental period. However, there was no adult emergence from soybean and kidney bean where the contents were 1.32 and 1.43 respectively (**Table 26**).

PLATE 8



1. Green gram
(*Vigna radiata* Linn.)



2. Grass pea
(*Lathyrus sativus* L.)

3. Cow pea (black-eyed)
(*Vigna catiang* Walp.)

4. Red gram
(*Cajanus cajan* Milsp.)

5. Pea
(*Pisum sativum* L.)

6. Bengal gram
(*Cicer areitinum* L.)

7. Lentil
(*Lens esculentum* Moench.)

8. Black gram or Urd
(*Vigna mungo mungo* L.)

9. Horse gram
(*Dolicos biflorus* Roxb.)

10. Moth bean
(*Vigna aconitifolia* Jacq.)

11. Soybean
(*Glycine max* Merr.)

12. Kidney bean
(*Phaseolus vulgaris* L.)

13. Black gram or thakri kalai
(*Vigna mungo silvestris* L.)

14. Small pea or garden pea
(*Pisum arvense* L.)

Photoplate 8. Photographs of fourteen species of legume seeds

Table 21. Seed weight (g) of stored pulses in summer

(Average of 3 seasons)

Pulse	Weight of single seed (g)		
	No. of Observations / season	Range	Mean ± S.D
Kidney bean	6	0.45 – 0.82	0.64 ± 0.18
Soybean	8	0.11 – 0.13	0.12 ± 0.01
Pea	6	0.24 – 0.28	0.26 ± 0.02
Small pea	7	0.14 – 0.20	0.17 ± 0.03
Horse gram	8	0.02 – 0.26	0.25 ± 0.001
Black gram	6	0.03 – 0.04	0.03 ± 0.005
Bengal gram	9	0.14 – 0.20	0.16 ± 0.03
Thakri kalai	8	0.03 – 0.04	0.03 ± 0.004
Cowpea	9	0.65 – 0.70	0.57 ± 0.03
Lentil	6	0.01 – 0.01	0.01 ± 0.02
Moth bean	6	0.03 – 0.04	0.03 ± 0.005
Red gram	7	0.15 – 0.19	0.17 ± 0.002
Green gram	7	0.04 – 0.03	0.03 ± 0.002
Grass pea	7	0.03 – 0.04	0.03 ± 0.002
SEM ±			0.13
C.D at %			0.25

Table 22. Thickness (mm) of the seed coat of stored pulses

(Measurement of the thickness of seed coats is in millimeter)

Pulse	Thickness of seed coat (mm)		
	No. of observations	Range	Mean ± S.D
Kidney bean	08	0.152 – 0.176	0.164 ± 0.01
Bengal gram	08	0.112 – 0.176	0.138 ± 0.02
Small pea	08	0.088 – 0.112	0.109 ± 0.014
Cowpea	10	0.096 – 0.120	0.106 ± 0.006
Grass pea	08	0.096 – 0.112	0.104 ± 0.007
Black gram	08	0.08 – 0.112	0.097 ± 0.012
Horse gram	08	0.064 – 0.112	0.092 ± 0.01
Thakri kalai	09	0.064 – 0.012	0.09 ± 0.02
Red gram	08	0.08 – 0.084	0.082 ± 0.007
Pea	09	0.08 – 0.102	0.081 ± 0.009
Green gram	08	0.064 – 0.08	0.078 ± 0.01
Soybean	08	0.064 – 0.08	0.065 ± 0.01
Moth bean	08	0.064 – 0.072	0.064 ± 0.008
Lentil	08	0.044 – 0.072	0.048± 0.01
SEm ±			0.07
CD at 5%			0.15

Table 23. Moisture of stored pulses in summer

Moisture (%)			
Pulse	**No. of Observations**	**Range**	**Mean ± S.D**
Kidney bean	06	7.52-8.02	7.76 ± 0.25
Soybean	05	5.12-6.04	5.65 ± 0.47
Pea	07	5.49-6.99	6.26 ± 0.75
Small pea	07	5.61-6.02	5.81 ± 0.20
Horse gram	04	5.04-5.13	5.09 ± 0.04
Black gram	06	5.38- 6.20	5.84 ± 0.42
Bengal gram	06	5.92-6.29	6.08 ± 0.18
Thakri kalai	06	5.63-6.02	5.75 ± 0.23
Cowpea	06	5.84-7.21	6.67 ± 0.73
Lentil	06	5.41-6.12	5.78 ± 0.35
Moth bean	04	5.72-6.03	5.85 ± 0.15
Red gram	07	6.24-7.03	6.55 ± 0.41
Green gram	07	5.91-6.01	6.21 ± 0.30
Grass pea	07	5.69-6.21	5.97 ± 0.30
SEm ±			0.26
C.D at %			0.52

Table 24. Phenol contents of fourteen species of stored pulses

Phenol contents (milligram /gram)			
Pulse	**Number of Observation**	**Range**	**Mean ± S.D**
Kidney bean	06	1.40 –1.48	1.43 ± 0.03
Soybean	06	1.32 – 1.35	1.32 ± 0.02
Pea	07	0.90 – 0.96	0.92 ± 0.02
Small pea	07	0.86 – 0.89	0.87 ± 0.01
Horse gram	06	0.77 – 0.82	0.79 ± 0.02
Black gram	06	0.71 – 0.77	0.74 ± 0.03
Bengal gram	06	0.68 – 0.72	0.70 ± 0.02
Thakri kalai	06	0.65 – 0.75	0.68 ± 0.03
Cowpea	06	0.65 – 0.70	0.67 ± 0.03
Lentil	06	0.62 – 0.66	0.64 ± 0.01
Moth bean	06	0.60 – 0.65	0.62 ± 0.02
Red gram	07	0.50 – 0.57	0.54 ± 0.02
Green gram	07	0.40 – 0.55	0.48 ± 0.04
Grass pea	07	0.27 – 0.35	0.31 ± 0.03
SEm ±			0.008
C.D at %			0.01

Table 25. Ovipositional preference, adult emergence and total developmental period of C. *chinensis* and C. *analis* in reference to seed weight, thickness of seed coat, moisture and phenol content of fourteen.

Pulses	Oviposition (no)		Adult emergence (%)		Development period (d)		Single seed weight (g)	Thickness of seed coat (mm)	Moisture (%)	Phenol contents (mg/g)
	C. chinensis	*C. analis*	*C. chinensis*	*C. analis*	*C. chinensis*	*C. analis*				
Green gram	99.3	86.3	63.3	44.1	23	26	0.037	0.078	6.14	0.48
Grass pea	81.6	81.0	61.1	44.4	23	30	0.034	0.104	5.97	0.31
Cowpea	87.0	82.6	53.3	51.6	24	26	0.190	0.106	6.67	0.67
Red gram	69.0	82.0	67.3	65.3	26	26	0.126	0.082	6.55	0.54
Bengal gram	93.0	74.3	36.8	40.0	25	27	0.166	0.138	6.08	0.70
Pea	72.0	72.6	33.3	30.5	28	31	0.260	0.081	6.26	0.82
Lentil	72.3	65.3	71.0	18.3	22	28	0.017	0.050	5.78	0.64
Black gram	77.3	88.6	06.0	26.6	30	28	0.038	0.091	5.84	0.74
Horse gram	67.3	74.0	49.0	19.1	24	29	0.025	0.092	5.09	0.79
Moth bean	70.0	75.3	57.0	30.8	23	26	0.035	0.064	5.85	0.62
Soybean	59.6	71.6	0.0	0.0	-	-	0.120	0.065	5.65	1.32
Kidney bean	33.0	49.3	0.0	0.0	-	-	0.640	0.164	7.76	1.43
Thakri kalai	78.0	92.0	06.8	16.3	31	29	0.035	0.097	5.85	0.68
Small pea	50.6	65.3	0.0	0.0	-	-	0.173	0.109	5.81	0.87
SEm±	**2.98**	**2.37**	**1.74**	**0.87**	**0.85**	**0.53**	**0.13**	**0.07**	**0.26**	**0.008**
CD at 5%	**6.44**	**4.69**	**3.76**	**1.82**	**1.84**	**1.11**	**0.25**	**0.15**	**0.52**	**0.01**

Table 26. Association of physico-chemical characters of pulses seed with oviposition, adult emergence and total developmental period

(**) = highly significant at 1%
(*) = significant at 5%

Physico-chemical characters of seed	Oviposition (no.)		Adult emergence (%)		Total developmental Period (d)	
	C. chinensis	*C. analis*	*C. chinensis*	*C. analis*	*C. chinensis*	*C. analis*
Moisture (%)	- 0.325	- 0.396	- 0.118	0.107	- 0.262	- 0.303
Single seed weight (g)	- 0.635*	- 0.706*	-0.430	0.311	- 0.524*	- 0.568*
Seed soat thickness (mm)	-0.279	- 0.356	- 0.415	- 0.128	- 0.285	- 0.325
Phenol content (mg)	0.750 **	.671**	0.730**	0.741**	0.718**	0.769**

4.5. Biosystematics and sexual dimorphism of the egg parasitoids, *Uscana mukerjii*

4.5.1. Taxonomy and historical back ground:

The family Trichogrammatidae can be separated from other hymenopteran families by the presence of 3 segmented tarsi, forewings are short, broadly rounded epically; distal cilia arranged in rows of distinct lines; veins *m* and *st* united to form a strong backward curve; hind coxae not enlarged; mesopleura impressed and axillae triangularly advanced into scapula in front of tegulae (**Appendix 1**). This family exclusively includes small sized wasps which can parasitize the eggs of insect pests (Richard and Davis, 1983 and Narendran, 2000).

The *Chaetotricha* Girault can parasitize the eggs of different species of bruchids (Coleoptera: Bruchidae) although a few species are also associated with the eggs of buprestids (Coleoptera : Buprestidae). About 166 species have been so far been described under the genus *Chaetotricha* (=*Uscana*) and 11 species have been reported with known hosts of which as many as 9 species parasitize the eggs of bruchids alone (Huis *et al.*, 1991a).

<u>Systematic position</u>

Order – Hymenoptera

Family – Trichogrammatidae

Subfamily – Trichogrammatinae

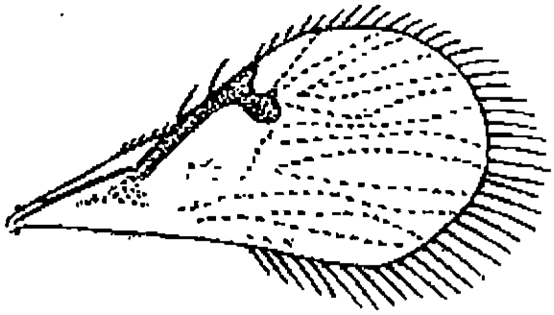
Tribe – Trichogrammatini

Genus – *Uscana*

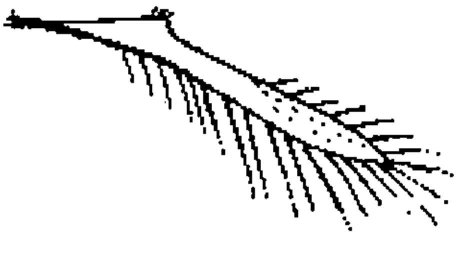
Species – *mukerjii*

Head

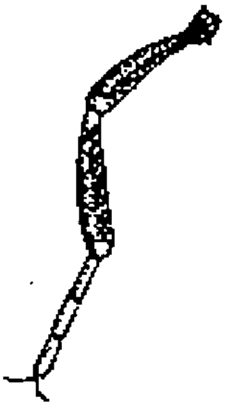
Antennae



Fore wing



Hind wing



Hind leg

Fig. 21. Diagram of *Uscana mukerjii* (Mani)

Previous report, distribution and host :

Mani (1935) : *Uscana* (= *Chaetotricha*) *mukerjii*, *Rec. Indian Mus.*, **37** :337- 338.
Mukerji and Bhuya (1936): *Bol. Soc. Brazil, Agron.*, **5**: 441
Chatterji (1953) : *Indian J. Ent.*, **16:** 77.
Steffan (1954) : *Uscana mukerjii* (Mani), *Bull. Mus. Hist. Nat. Paris 2e ser.*, **26:** 667-673.
De Luca (1965) : *Uscana mukerjii* (Mani), *Stored Prod. Res.*, **1**: 51-98.
Pajni and Singh (1973) : *Uscana mukerjii* (Mani), *Res. Bull. Panjab Univ.*, **24**: 163-164
Mani (1989) : *Uscana mukerjii*, *The Fauna of India and Adjacent Countries*, **2** :1353-1377.
Kapila and Agarwal (1965):*J. Stored Proc. Res.*, **31**: 334-341
Pajni *et al.*(1996) :*Res. Bull. Punjab Univ.*, **46:** 77-87.

Type species : *Chaetotricha* (= *Uscana*) *semifumipennis* Girault (1911).

Type species : *Hawii,U.S.A.*

Host : Bruchids (*Callosobruchus chinensis, C. maculatus, C. analis*).

Distribution : Hawii, U.S.A.; Africa; france and North-west plain, North-east plain and Northern hill zone of India (**Appendix X11**)

4.5.2. Morphology and sexual dimorphism

Adult male : Length 0.40 - 0.43 mm body at a glance generally brownish to black. Head deeply and broadly striated in front and behind. Length of the head 0.11-0.12 mm and width 0.12-0.15 mm. Antennae light brown, densely clothed with moderate fine setae (except scape and pedicel), stout, with 7 segments; pedicel about 0.60-0.65 times of scape; club about 2.5 times pedicel, gradually tapering to the rounded tip, more slender than the funicle, the basal 2 segments sub equal, apical segment slightly more slender and longer; ocellocular space sub equal to ocellar diameter; compound eye almost oval and crimson-red color, outer surface of the compound eye yellowish-brown (**Plate 11**). Thorax is 0.15-0.22 mm in length and 0.18-0.20 mm in width; brownish, about 0.50 times of body; mesonotum and scutellum smooth; legs brownish except the dirty white or pale brown bases and tips of femora and tibiae; length of tibia > Femur > tarsus; tarsi with 3 segments; hind coxae not enlarged; 1^{st} tarsal segment > 2^{nd} > 3^{rd}; length of forewing (0.41-0.43 mm), about 2 times as long as wide; marginal frimge or discal cilia short and cover 0.75 part of the total marginal area; stigmal vein (*st*) forming an angle with the vein m. hind wing 0.28-0.29 in length, slender, apical portion pointed and with 3 hamuli. Abdomen 0.12 - 0.19 mm long and 0.18-0.19 mm width, shorter than the length of thorax; yellowish-brown in color and dorsal segmented area slightly sclerotised; aedeagus with bacilliform apodeme (**Table 27**).

Adult female : The morphological features of Female (**Plate 5**) are almost similar to male except size. Body length is 0.44-0.51 mm; the length of abdomen is longer than the male (length 0.24-0.28 mm); length (0.13-0.16 mm) and width (0.14-0.17 mm) of thorax is always shorter than the male; length of forewings (0.02-0.03 mm) and hind wings (0.20-0.30 mm) also shorter than male (**Table 27**).

Table 27. Sexual dimorphism of *Uscana mukerjii* in respect of adult body morphometry

(All measurements are in millimeter)

Uscana mukerjii	Body length of adult		Length of head		Width of head	
	Male	Female	Male	Female	Male	Female
No. of individuals	13	12	12	13	13	11
Range	0.40 - 0.43	0.44 - 0.51	0.11 - 0.12	0.08 - 0.11	0.12 - 0.15	0.12 - 0.14
Mean ± SD	0.41 ± 0.01	0.47 ± 0.04	0.14 ± 0.0006	0.1 ± 0.01	0.14 ± 0.0009	0.13 ± 0.01

Table 27. Contd.

Width of abdomen		Length of antennae		Length of forewing		Width of forewing	
male	female	male	female	male	female	male	female
13	09	12	10	10	10	09	11
0.08 - 0.19	0.2 - 0.24	0.1 - 0.12	0.09 - 0.12	0.41 - 0.43	0.38 - 0.42	0.100 - 0.108	0.18-0.2
0.19 ± 0.0009	0.22 ± 0.01	0.1 ± 0.0006	0.11 ± 0.0008	0.42 ± 0.01	0.4 ± 0.01	0.104 ± 0.0002	0.19 ± 0.01

4.6. Studies on the role of biology and percentage of parasitization of the, *Uscana mukerjii* (Mani)

The *Uscana mukerjii* (Hymenoptera: Chalcidoidea: Trichogrammatidae) parasitizeds singly on an eggs of *Callosobruchus chinensis* and other bruchids (**Plate 11**) The bruchids are particularly suitable for control through the agency of egg-parasitoids because they lays eggs on the surface of the pulses.

4.6.1. Ovipositional preference

After mating the females climbed to the pulse seed and detected host's egg with their antennae. This process was referred to as 'drumming' by Strand and Vinson (1984). Then it

PLATE 11

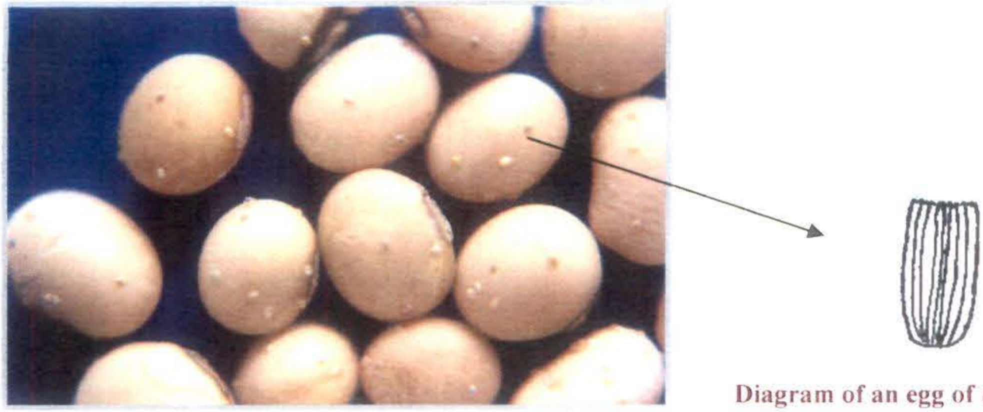
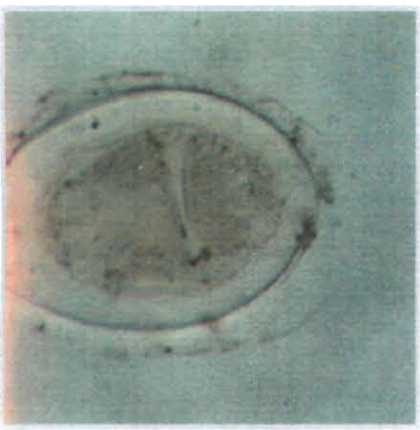


Diagram of an egg of *U. mukerjii*

Eggs of pulse beetle parasitized by *Uscana mukerjii*



Larval stage

Pupal stage

Adult male

Adult female

Photoplate 11. Microphotographs of different biological stages of *Uscana mukerjii* (Mani)

drilled a hole on the egg-chorion for egg-laying. The females were very specific to prefer eggs for oviposition and usually rejected the old eggs (**Table 28**) They preferred most (56.8±7.4) the eggs of 0 to 12 hours, followed by 12 to24 hrs (47.6 ± 9.6) and 24 to 48 hrs (31.5 ± 4.6).

4.6.2. Developmental period

The developmental period was studied in the laboratory in different seasons. The data are presented in the **Table 29**. The longest developmental period of 15.0 ± 3.5 days was recorded during winter followed by autumn (8.0 ± 2.01 days), summer (6.5 ± 1.39 days) and rainy seasons (6.4 ± 1.42 days).

4.6.3. Life span of the adult

The life span of adult (**Table 29**) parasitoids differed not only in the two sexes but also in the mated and unmated individuals of each sex. In general the life span of the females was shorter than that of the males. Maximum life span of 10.7 ± 0.65 days was recorded for the unmated males during winter whereas the life span of unmated females was close (9.5 ± 1.52 days) to the females. Minimum life span 4.1 ± 0.9 days was recorded during rainy season. The life span of both mated and unmated adults of both the sexes did differ considerably during summer and rainy seasons.

4.6.4. Sex ratio

The sex ratio (male: female) did not differ in different seasons (**Table 29**) although the lowest of 1: 2.94 was recorded during summer. In every season the sex ratio of the parasitoid was predominated by females and went up to 1: 2.84 during autumn followed by rainy (1:2.49) and winter (1: 2.07).

4.6.5. Percentage of parasitization

Eggs of *C. chinensis* parasitized by *U. mukerjii* could be identified from the healthy eggs by yellowish to black coloration of the embryo of the parasitoid. The larvae became deep yellow, followed by brown color of the early pupae and black of the late pupae (**Plate 11**).The result of per cent parasitization is furnished in the table. The mated females parasitized up to a maximum of 49.6 ± 2.59 (%) during summer which was very close to the per cent parasitization during rainy seasons (48.9 ± 2.71%). During autumn, the percentage of parasitization recorded was 39.5 ± 3.02 and the lowest percentage was 35.2 ± 3.19% during winter (**Table 30**).

Table 28. Ovipositional preference of *U. mukerjii* to *C. chinensis* eggs of different ages

Age of host eggs (in hours)	Number of egg laid /mated female Mean ± S.D.
0-12	56.8 ± 11.0
12 -24	52.6 ± 12.6
24-48	31.5 ± 4.6

Table 29. Development period, adult life span and sex ratio of *U. mukerjii*

(The figures are averages of 3 years ± S.D.)

Seasons (Temperature) (°C)	Development period (day)	Adults longevity (day)				Sex ratio
		Male		Female		Male : Female
		Mated	Unmated	Mated	Unmated	
Winter (18.42 –21.5°C)	15 ± 3.50	9.5 ± 1.2	10.7 ± 0.65	7.25 ± 1.11	9.5 ± 1.52	1 : 2.07
Autumn (24.2 – 26.9 °C)	08 ± 2.01	6.2 ± 0.9	6.8 ± 0.91	5.70 ± 0.21	6.12 ± 1.02	1: 2.84
Summer (26.9 –30.1 °C)	6.5 ± 1.39	4.2 ± 0.8	5.1 ± 0.62	4.16 ± 0.71	4.92 ± 0.79	1: 1.94
Rainy (26 – 30 °C)	6.4 ± 1.42	4.1 ± 0.90	5.2 ± 0.12	4.02 ± 0.98	4.54 ± 0.44	1: 2.59

Table 30. Number of host eggs parasitized by one mated female adult of *U. mukerjii*

(The figures are averages of 3 years ± S.D.)

Seasons (Temperature °C)	Number of egg parasitized by one mated female Mean ± S.D.
Winter (18.42 –21.5°C)	35.2 ± 3.19
Autumn (24.2 – 26.9 °C)	39.5 ± 3.02
Summer (26.9 –30.1 °C)	49.6 ± 2.59
Rainy (26 – 30 °C)	48.9 ± 2.71

Fig. 23. Parasitization potentiality (%) of *Uscana mukerjii* in different seasons

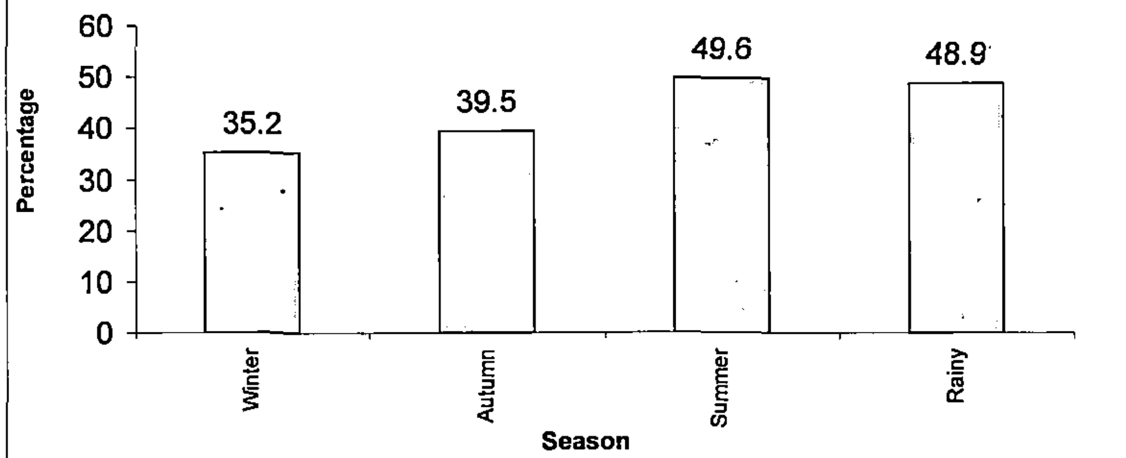
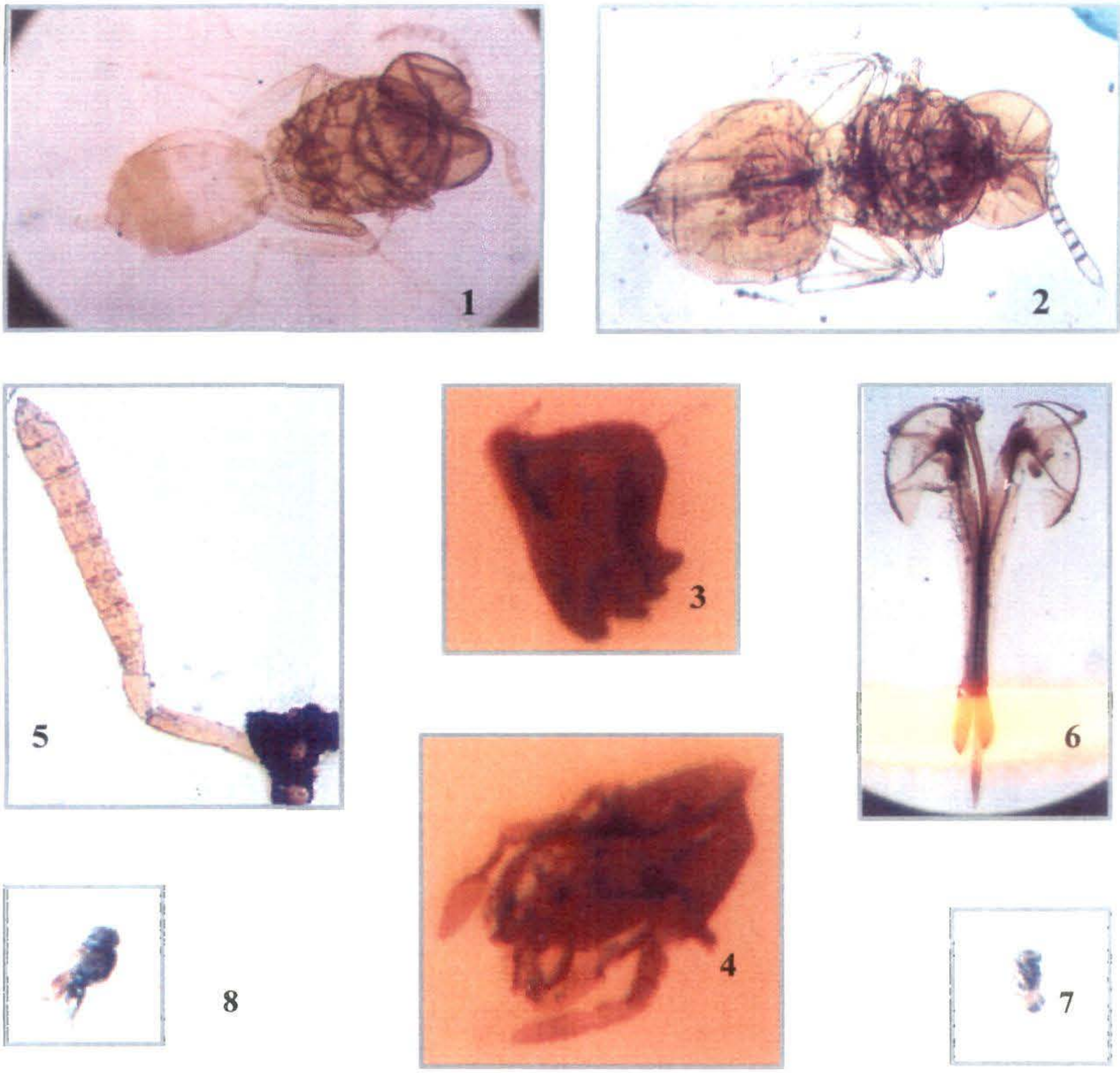


PLATE 9



Photomicrograph 9. **Morphological features of *Dinarmus vagabundus* (Timberlake)**

1. **Male adult 30x**
2. **Female adult 30x**
3. **Mandible 950x**
4. **Maxillae and labium 900x**
5. **Antennae 80x**
6. **Ovipositor apparatus 80x**
7. **Lateral view of female adult 7x**
8. **Dorsal view of male adult 6x**

4.7. Biosystematics, morphology and sexual dimorphism of *Dinarmus vagabundus*

4.7.1. Taxonomy, historical back ground and distribution

Systematic position :

Order - Hymenoptera

Super family – Chalcidoidea

Family – Pteromalidae

Subfamily – Pteromalinae

Tribe – Pteromalini

Genus – *Dinarmus*

Species – v*agabundus*

Genus	:	***Dinarmus* subg. *Dinarmus* Thomson**
		1878 *Dinarmus* Thomson, *Hymen Scand.*, **5**: 56.
Type species	:	*Dimachus* (*Dinarmus*) *acutus* Thomson
Type locality	:	Europe
Distribution	:	Hawii, U.S.A.; France; Brazil, Pakistan; Ceylon and North-east plain, Northern hill and South part of India (**Appendix X11**)
Host	:	Bruchids.

Previous description :

In course of a survey during 1999-2000, in the terai region of West Bengal , India a very interesting hymenopteran ecto-parasitoid, *Dinarmus vagabundus* (Timberlake) (Chalcidoidea : Pteromalidae : Pteromalinae) was collected from stored black gram (*Vigna mungo* var. *mungo*) infested by the pulse beetles, *Callosobruchus chinensis* and *C. analis* (Coleoptera : Bruchidae). The genus *Dimachus* subg. *Dinarmus* Thomson was first described by Thomson (1878) based on *D. acutus* Thomson as its type. Ashmead (1904) redescribed and ranked to as genus *Dinarmus* which belongs to the subfamily Pteromalinae of Pteromalidae.

Timberlake (1926) first described and separated *Dinarmus vagabundus* (Timberlake) from other allied species of *Dinarmus* by original designation .Mani (1939), Boucek *et al.* (1978), and Mani(1989) redescribed and illustrated its morphological characteristics. Unfortunately, no comprehensive study of this species with special emphasis to their mouthparts, ovipositor apparatus and sexual dimorphic characteristics has been published so far. However, the information on the occurrence and distribution of this parasitoid in India is confined only to some occasional local records. Here is an attempt to provide a comprehensive account in a reversionary framework. The type locality and host of *Dinarmus vagabundus* (Timberlake) is Hawii and bruchids respectively (Mani,1989). It has been frequently recorded from Brasil (Lima, 1942);

France (Rojas *et al.,* 1988); Pakistan and Ceylon (Boucek *et al.,* 1978 and Mani, 1989). It was first recorded from India by Mani (1939). It was also reported as potential gregarious ecto-parasitiod of bruchids from Northern India (Kundra, 1976) and Southern India (Mani, 1989 and Raja *et al.*, 2000) and North-east plain of India by Ghosal *et al.*, 2003.

***Dinarmus* vagabundus (Timberlake)**

1926	*Brochobius vagabundus*,	Timberlake, *Proc. Hawaii Ent. Soc.*, **6**:305-307.
1939	*Brochobius vagabundus*,	Mani, *Indian J. Ent.*, **1**: 69-88.
1942	*Dinarmus vagabundus*	Lima, *Bol.Soc. Brazil,Agron.*, **5**:441.
1962	*Dinarmus vagabundus*	Chema and Misra, *Curr. Sci.*, **31**: 21.
1977	*Dinarmus vagabundus*	Dhir, Curr. Sci., **46**: 63-70
1978	*Dinarmus vagabundus*,	Boucek, Subba Rao & Farooqi, *Oriental Insect*, **12**(4): 442
1988	*Dinarmus vagabundus*	Rojas *et al.*, *Entomol.Exp. et Applicata*, **46**: 63-70
1989	*Dinarmus vagabundus*,	Mani, *The Fauna of India and the Adjacent Countries*, **1**: 567-568.
1994	*Dinarmus vagabundus*	Alebeek *et al., Proc. Selec. Exp. Appl. Ent.,* **5:** 145-150
2000	*Dinarmus vagabundus*	Raja *et al. Indian J. Exp.Bio.,* **38**: 290-292
2003	*Dinarmus vagabundus*	Ghosal *et al., Proc. Zool. Soc. Calcutta,* **56**: 21-26.

4.7.2. Morphology and sexual dimorphism

Adult male : Body length is 1.58-2.31 mm. Color of the body is black except the anterior half of the abdomen (yellowish-brown); front surface of the head and thorax is black but with greenish reflections (**Table 31, Plate 9** and **10**).Head width is almost 2-times larger than the length, and is also larger than the maximum width of the thorax or abdomen; compound eyes ovate, bulging and devoid of cilia; ocelli 3, very small, round and arranged in obtuse triangle. The length of antennae is 0.81-0.95mm; elbowed and 13 segmented; 0.40mm part of the scape is yellowish-white, rest of antennae brownish-yellow; scape long; pivot is triangular subequal to the total summation of the first three segments of flagellum; annuli 2; apical 3 segments of flagellum form a typical club.Thorax is well developed; metapostnotum fused with the first abdominal tergite to form propodeum; pronotum disconnected from prothorax and attached to the front part of the mesothorax; neck of the propodeum short.Leg is yellowish-brown except coxae (length 1.36-1.58mm.); femur long, partially sclerotised; apical portion of tibia with short spines, tibial spur single; tarsus 5 segmented, spinose, the length of tarsal segments are in the descending order of 1st >2nd >5th >3rd >4th.Fore wing (length 1.18-1.2mm.) is membranous; hyaline; spotted upto 0.75 part; marginal fringe short, occupying about half of the total marginal area; single solitary compound vein; post marginal vein (pm.) is subequal to stigmal vein (*st*); sub-marginal vein (*sm*) is setose; stigmal vein (*st*) is ovate.Hind wing (length 0.91-0.96mm.) is blunt apically; membranous, hyaline, spotted; marginal fringe short, spaced by a distance equal to 0.40 part of the wing margin; an unbranched single vein (r+m), setose; 3 frenal hooks or hemulli along the costal margin.Gaster is longitudinally ovate; smaller than the thorax; 5 segmented;

part of the wing margin; an unbranched single vein (r+m), setose; 3 frenal hooks or hemulli along the costal margin.Gaster is longitudinally ovate; smaller than the thorax; 5 segmented; anterior half is yellowish-brown; anal point of hypo-pygium short, yellowish-brown, setose at the apex (**Table 31**).

Adult female : Body length is 1.66-2.41mm. Color of the body is black; front surface of head and thorax black with bluish reflection; gaster black with brassy luster (**Table 31; Plate 9** and **10**). Antennae (length 0.78-0.85mm.) is 13 segmented; Annuli 3, where 1st >2nd >3rd and the 3rd one is sub square; length is somewhat smaller than that in male.Thorax is always smaller than gaster and width is sub equal to head, scutellum a little wider than the length; neck of propodeum short.Leg (length 1.35-1.41mm.) is always small in comparison to that of adult male.Fore wing (length 1.20-1.50 mm.) and hind wing (length 0.90-1.00 mm.) are longer than those of an adult male. Gaster is longitudinally ovate; ovipositor long (length 0.70-0.76 mm.) and originate from tip of the gaster; long forward extension of the 9th abdominal tergum provide a tall hoist or stinger for deep drilling ovipositor shaft.

Mouthparts : Mouthparts (**Plate 9**) typically orthopteroid, characterized by the great flexibility of the maxillae-labium complex. Marginal end of the labrum (length,0.03 mm) carinated. Mandibles (length, 0.02-0.03mm) quadric-dentate and maxillae with 4 segmented maxillary palpi ; cardo well developed and yellowish in color, stipes long and deep brownish-black and galea yellow; labium well developed, 3 segmented palpi with first segment deeply sclerotised, glossa short and bifid (**Table 31**).

Ovipositor apparatus : Length 0.70-0.76 mm.. It comprises of the lateral gonophyses of the 9^{th} segment forming the sheath of the sting; the median gonophyses of the 9^{th} segment fused together as the sting canal; the valvifers of the gonophyses of the 8^{th} segment (stylet) articulate with the homologous parts of the 9^{th} segment instead of the tergite; the stylet modified into sting (length 0.07-0.11mm.) lying with the retraction of the 8^{th} segment just like a complicated stinging apparatus within the sting chamber. The long forward extensions of the 9^{th} abdominal tergum provide a long hoist for deep drilling ovipositor shaft (**Table 31** and **Plate 9**). The modifications of the ramus helps in turning the ovipositor shaft to a vertical position of action from the horizontal position of repose with the help of modified ovipositor muscles (Saxena *et al.*, 1997).

Sexual dimorphism : Body length (1.87mm) and wing span (2.97) always shorter in male than those in female. Length of antenna (0.87) and hind legs (1.39) are longer in female than those of male (**Plate 9**). In male, front surface of head and thorax is black with greenish reflection. Anterior half of the gaster is yellowish-brown in color. Abdomen always shorter than the combined length of head and thorax. Antennae 13 segmented: 1.1.2.6.3. (annuli 2, flagel 6).

Table 31. Sexual dimorphism of *D. vagabundus* uin respect of adult body morphometry
(All measurements are in millimeters)

Dinarmus vagabundus	Body length of adult		Body width of adult		Length of antennae		Length of fore wing		Width of fore wing		Length of hind wing	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
	1	2	3	4	5	6	7	8	9	10	11	12
Number of individuals	10	10	10	10	9	9	8	8	8	8	8	7
Range	1.58-2.31	1.66-2.41	0.61-0.76	0.55-0.80	0.81-0.95	0.78-0.85	1.18-1.20	1.20-1.58	0.71-0.78	0.71-0.78	0.91-0.96	0.28-0.31
Mean ± SD	**1.87±0.25**	**2.04±0.28**	**0.71±0.05**	**0.72±0.08**	**0.85±0.03**	**0.80±0.02**	**1.19±0.01**	**1.41±0.13**	**0.72±0.01**	**0.75±0.02**	**0.94±0.01**	0.29±0.00

Table 31. Contd.

Dinarmus vagabundus	Width of hind wing		Wing span		Length of hind leg		Length of ovipositor apparatus	Length of stinger	Length of the mandible
	Male	Female	Male	Female	Male	Female			
	13	14	15	16	17	18	19	20	21
Number of individuals	8	7	8	8	9	9	9	7	6
Range	0.25-0.28	0.28-0.31	2.69-3.08	2.75-3.83	1.35-1.41	1.36-1.58	0.70-0.76	0.07-0.11	0.029-0.035
Mean ± SD	**0.26±0.01**	**0.29±0.01**	**2.97±0.05**	**3.79±0.03**	**1.39±0.04**	**1.47±0.06**	**0.73±0.02**	**0.09±0.01**	**0.031±0.01**

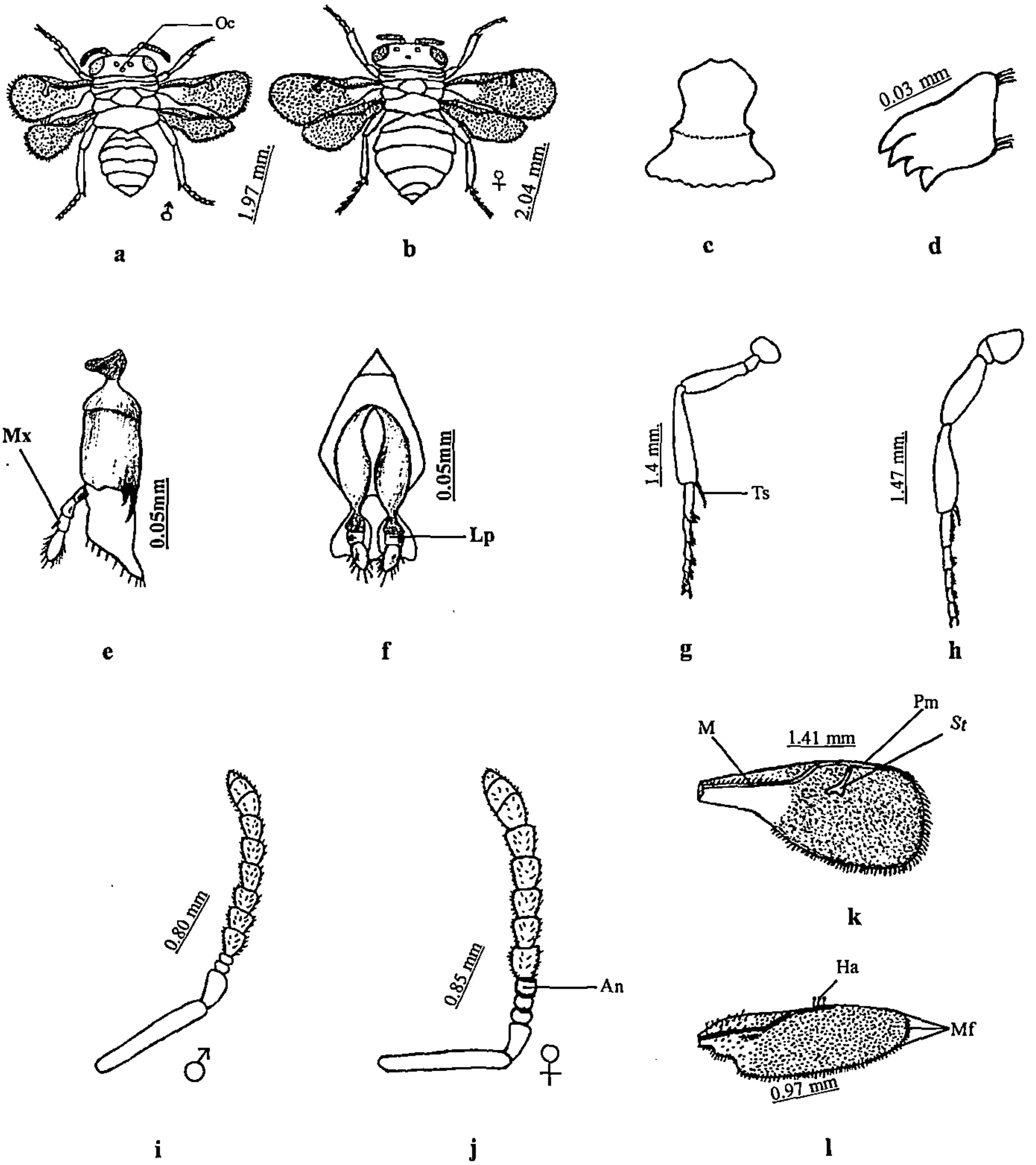


FIGURE 22

Morphological features of *Dinarmus vagabundus* (Timberlake)

a. Dorsal view of adult male b. Dorsal view of adult female c. Labrum d. Mandible e. Maxillae f. Labium g. Fore leg h. Hind leg i. Antennae (Male) j. Antennae (Female) k. Fore wing l. Hind wing

Abbreviation used : An., annulus; Oc., Ocellus; Mx., Maxillary palp; Lp., Labial palp; Ts., Tibial spur; M., Median vein; Pm., Post median vein; St., Stigmal vein; Mf., Marginal fringe; Ha., Hamullus

4.8. Studies on the role of biology and percentage of parasitization of *D. vagabundus*

4.8.1. Biology

Being a larval-pupal parasitoid of *C. chinensis*, the females of *D. vagabundus* pierced the seed coat of pulses by its sharp and pointed ovipositor. After access to larva/pupa the female oviposited on the outer surface of the integument. Single to several eggs were laid on a single host larva/pupa. The adult males were always shorter than the females and were polygamous. The courtship duration during summer and winter was recorded 56.23 ± 6.33 and 47.73 ± 8.47 seconds respectively. The mean mating duration was 14.14 ± 1.47 seconds during summer and 13.79 ± 1.04 seconds during winter. The fecundity was studied during summer and winter seasons only. It was higher during summer (42.8 ± 2.89) than in winter (38.5 ± 1.47). The time took for completion of life cycle (egg-adult) during winter was 51.71 ± 2.43 days which was much longer than in summer (19.14 ± 2.31 days). The life span of adult females was always longer than that of males in every season. The female survived for 7.71 ± 1.11 days and 11.88 ± 2.05 days during summer and winter respectively. The male life span was recorded 5.55 ± 0.75 days during summer and 9.88 ± 2.57 days during winter. The sex ratio (male: female) was 1: 2.07 during summer and 1:1.55 during winter (**Table 32**).

4.8.2. Percentage of parasitization

The number of adults emerged out of a single green gram, Bengal gram, red gram and cowpea seed each infested with single larva/pupa of *C. chinensis* was 2.71 ± 1.52, 2.96 ± 0.98, 3.01 ± 1.08, and 3.66 ± 1.29 respectively during summer.

The per cent parasitization the larva and pupa of *C. chinensis* by *D. vagabundus* on green gram, bengal gram, cowpea and red gram stored pulses during summer and winter is provided in the **Table 33**. The mean parasitization (%) of *D. vagabundus* on host pulses was always higher during summer (20.82±4.65). Mean per cent parasitization of two seasons on 4 different species of pulses could be arranged in the followed descending order: cowpea (25.90%) > red gram (20.38%) > green gram (17.96%) > chick pea (15.52%).

Table 32. Biology of *Dinarmus vagabundus* and temperature snd relative humidity of rearing room

(Mean of 3 years, 1999-2001)
The values are the mean ± S. D. Figures in the parenthesis are the ranges

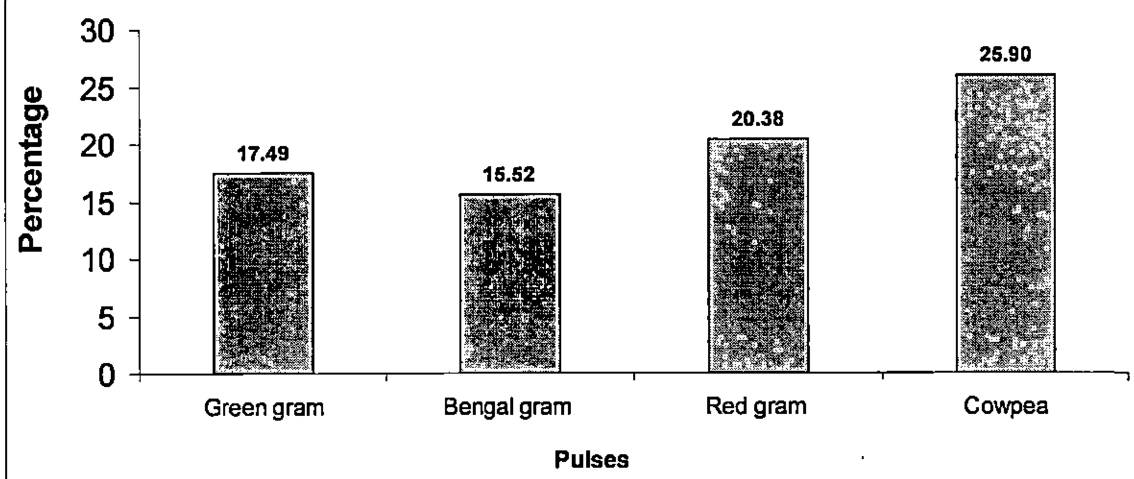
Biology	Seasons		
	Summer	Winter	Average of seasons
Courtship duration (second)	56.26 ± 16.33 (40-73)	47.73 ± 18.47 (29-64)	51.98±17.4 (34.5-68.5)
Mating duration (second)	14.11 ± 1.47 (11.5-16.0)	13.79 ± 1.04 (11.0-15.0)	3.95±1.25 (11.25-15.5)
Fecundity/ female (number)	42.8 ± 2.89 (38-47)	38.5 ± 1.47 (31-42)	40.65±2.18 (34.5-44.5)
Life cycle (egg – adult) (day)	19.14 ± 2.31 (16-22)	51.71 ± 2.43 (48-54)	35.42±2.37 (32-38)
Longevity of adult male (day)	5.55 ± 0.75 (4-7)	9.88 ± 1.57 (7-12)	7.71±1.16 (5.5-9.5)
Longevity of adult female (day)	7.71 ± 1.11 (7-9)	11.88 ± 2.05 (8-15)	9.79±1.58 (7.5-12)
Sex ratio (male : female)	1:2.07	1 : 1.55	1 : 181
Average temperature °C	28.05	20.00	
Average r. h. (%)	64.63	63.92	

Table 33. Parasitization and emergence of adult *D. vagabundus* from a single larva/pupa of *C. chinensis*

(Average of 3 years, 1999-2001)
The values represent mean ± S.D. and the ranges in parenthesis

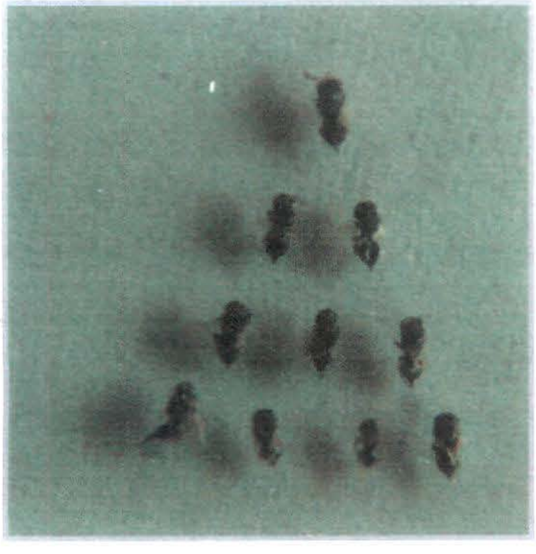
Pulse	Parasitization (%)			No. of adult / larva or pupa
	Summer	Winter	Average of two seasons	
Green gram	18.22 ± 5.26 (12 – 25)	16.77 ± 3.04 (13 – 21)	17.49 ± 4.15 (12.5 – 23)	2.71 ± 1.52 (1-4)
Bengal gram	16.33 ± 2.54 (13-19)	14.72 ± 2.54 (11 – 17)	15.52 ± 2.34 (12 – 18)	2.96 ± 0.98 (1-5)
Red gram	2172 ± 6.02 (16-28)	19.04 ± 4.16 (14 – 24)	20.38 ± 5.09 (15 – 26)	3.01 ± 1.08 (1-6)
Cowpea	27.01 ± 4.79 (22-32)	24.79 ± 3.48 (20 – 29)	25.9 ± 4.13 (21 – 30.5)	3.66 ±1.21 (1-7)
Mean	**20.82 ± 4.65 (12-32)**	**18.83 ± 3.30 (11-29)**	**19.82 ± 3.92 (11.5-30.5)**	**3.08 ± 1.91 (1-7)**

Fig. 24. Parasitization potentiality of *Dinarmus vagabundus*



Larvae of pulse beetle,
Callosobruchus chinensis Linn.

Pupae of pulse beetle ,
Callosobruchus chinensis Linn.



Adult female of *Dinarmus vagabundus*

Adult male of *Dinarmus vagabundus*

Photoplate 10. Host insect's (*C. chinensis)* larva and pupa and its parasitoid, *Dinarmous vagabundus* (Timberlake)

4.9. Pesticidal effect of plant oils on adult pulse beetle, C. *chinensis*

Five non-edible plant oils such as clove, neem, castor, chaulmoogra, and citronella and nine edible plant oils (mustard, niger, rice bran, soybean, coconut, sesame, sunflower, palm and safflower) were used to test their effectiveness against pulse beetle, *C. chinensis.*. The edible plant oils were applied at required concentration (v/v) of 0.05, 0.02 and 0.01 per cent and non-edible plant oils of 0.01, 0.005, 0.002 and 0.001 pre cent to test the effectiveness to kill the adult beetles.

4.9.1. Pesticidal effect of nine edible oils

The result presented in **table 34** indicated that the effectiveness of these oils on the mortality of adult beetles were statistically significant. A marked concentration dependant effect on adult mortality was observed. The highest mortality was recorded in all the cases at 0.05 % concentration and the lowest with 0.01 % concentration. The 0.05 per cent dose of safflower oil caused 100 % death of the adult. At 0.01 % concentration, mustard and niger oils showed no adult mortality. The relative effectiveness of the oils at 0.05 per cent was in the descending order of safflower > soybean > sesame > coconut > sunflower > rice-bran > mustard > niger > palm. The mortality percentage was nil in control (untreated) experiment.

4.9.2. Pesticidal effect of five non-edible oils

It was observed (**Table 35**) that non-edible oils at the concentration of 0.01 were very effective. The highest (100%) mortality at this concentration was the maximum in case of chaulmoogra oil (100%) followed by clove oil (90.0%), citronella (36.3%), and castor (10.0) and neem (9.00%). At subsequent lower concentrations (0.001, 0.002 and 0.005) neem and castor oils has no effect. The death caused due to both edible and non-edible oils differed significantly at different concentrations. The non-edible oils were more effective to cause the death of adult beetles. Among the all fourteen plant oils tested at 0.01% concentration, chaulmoogra (*Hydnocarpus kurzii*) oil appeared to express the best pesticidal effect on the adult beetle followed by clove, safflower, citronella, sesame and soybean. Uses of botanicals as protectants of stored grains have had long history of use by farmers. The actual mechanism of their toxicidal effect on insect is not known but the basis may either be physical or bio-chemical or both. In view of encouraging results obtained in this study, the chaulmoogra, clove, safflower, citronella, soybean and sesame oils appear to have distinct potentiality as bio-pesticides and good additives for the management of insect pests especially the bruchid pests (Coleoptera: Bruchidae) of stored pulses.

Table 34. Effectiveness of nine edible oils against the adults of *C. chinensis*

(Parentheses are the angular transformed values)

Edible plant oils	Mean death (%) after 24 hours exposure		
	Concentrations (v/v)		
	0.05 %	0.02 %	0.01 %
1. **Mustard**	66.0 (54.32)	13.3 (21.39)	00.0 (00.0)
2. **Niger**	65.3 (53.93)	19.6 (26.31)	00.0 (00.0)
3. **Rice bran**	68.0 (55.55)	39.3 (38.83)	15.6 (23.28)
4. **Soybean**	82.3 (65.13)	62.6 (52.32)	27.0 (31.28)
5. **Coconut**	78.0 (62.02)	26.6 (31.03)	16.0 (23.54)
6. **Sesame**	80.0 (63.44)	61.3 (51.54)	33.0 (35.05)
7. **Sunflower**	72.3 (58.27)	48.0 (43.05)	24.0 (29.31)
8. **Safflower**	100.0 (90)	68.6 (55.96)	37.3 (37.65)
9. **Palm**	65.0 (53.7)	37.6 (37.8)	23.3 (28.8)
CV (%)	**1.77**	**5.44**	**8.95**
SEM ±	**0.42**	**0.76**	**0.56**
CD at 5%	**1.57**	**2.85**	**2.10**

Table 35. Effectiveness of five non-edible oils against the adults of *C. chinensis*

(Parentheses are the angular transformed values)

Non-edible plant oils	Mean death (%) after 24 hours exposure			
	Concentrations (v/v) (%)			
	0.01 %	0.005 %	0.002 %	0.001 %
1. **Chaulmoogra**	100 (90.0)	77.6 (61.81)	48.0 (43.85)	22.6 (28.41)
2. **Neem**	26.6 (31.03)	16.0 (23.54)	00.0 (00.0)	00.0 (00.0)
3. **Castor**	10.0 (18.37)	00.0 (00.0)	00.0 (00.0)	00.0 (00.0)
4. **Clove**	90 (71.62)	58.0 (49.6)	32.0 (34.43)	26.0 (27.71)
5. **Citronella**	36.3 (36.27)	13.6 (21.67)	00.0 (00.0)	00.0 (00.0)
CV (%)	**6.32**	**4.26**	**7.01**	**10.89**
SEM ±	**1.45**	**0.66**	**0.65**	**0.57**
CD at 5%	**7.85**	**3.58**	**3.51**	**3.08**

4.10. Efficacy of different edible and non-edible oils in suppressing egg laying, emergence of adults and developmental period of C. *chinensis.*

4.10.1. Impact on the egg laying

The result presented in Table 36, indicats a marked effect of three different doses (0.05, 0.1 and 0.3 in 10g of pulses) on egg laying (number of eggs laid / female). There were declines in eggs laying with the increase of oil concentration and hence, extended storage duration of green gram seeds treated with different plant oils. At different days after storage (i.e. 30, 60, 90 and 120 days) the non-edible oils likely chaulmoogra and clove oil were more effective than citronella and neem oils. Among the edible oils, soybean oil was the most effective in suppressing egg infestation up to 120 days over the control at all levels of per cent concentration (v/w). Although the per cent concentration 0.3 (v/w) slowed most effective in all the oils used for the present investigation. Chaulmoogra oil suppressed to the highest extend of eggs 40.8 no./female at 0.3% concentration and was significantly superior to all other oils. Clove oil at 0.3% level appeared to next promising agent (34.8 eggs /female). Among the edible oils soybean at all levels of concentrations was superior to niger and mustard. The oil could protect the seeds well even up to 120 days (**Table 36**).

4.10.2. Impact on the developmental duration

It is evident from the data (**Table 37**) that mean developmental period was the highest (49.2days) on seeds treated with soybean oil at 0.3 percent concentration. The result was very close to the seeds treated with 0.3 percent concentration of chaulmoogra oil (46.5days). The developmental period in rest of the treatments was also significantly different in comparison to untreated seeds (control). However, the lengthening of different periods of *C.chinensis* evaluated in the present treatments were statistically significant from the (control) result and the lengthening in descending order in comparison to that of control was soybean (4.7 days)> chaulmoogra (2.9 days)> clove (2.7 days)> citronella (2.6 days)> neem (2.4 days)> rice bran (1.6 days)> (1.2 days) and niger (1.2 days) and mustard (1.3 days).

4.10.3. Impact on the emergence of adult

A trend of suppression of adult emergence was observed with increase in concentrations of the oils (Table 38). The emergence of adult beetle was suppressed to the highest extent in case of chaulmoogra oil followed by clove oil, neem oil, soybean oil, citronella oil, niger oil, rice bran mustard oil. At 30 days after application of chaulmoogra oil all the three concentration proved to be most effective, as there was no adult emergence. Clove oil treated seeds of green gram also showed significant result. These two treatments were significantly superior to all other plant oils. The citronella, neem and soybean oils at all the three levels appeared to be promising. The effectiveness of the oils persisted satisfactory up to 120 days (**Table38**).

Table 36. Efficacy of different plant oils in suppressing egg laying by *C. chinensis* at every 30 days after treatment up to 120 days

OIL	Conc. (v/w) (%)	Number of eggs laid / 100 (g) green gram seed					
		30 days	60 days	90 days	120 days	Mean	Number decrease over control
Rice bran	0.05	16.9	25.6	29.3	57.0	32.2	15.2
	0.10	16.0	23.0	24.6	55.0	29.6	17.1
	0.30	14.0	20.0	20.3	51.3	26.4	20.3
Niger	0.05	19.6	27.0	32.6	61.3	35.1	11.6
	0.10	18.6	22.0	29.6	51.0	30.3	16.4
	0.30	16.6	21.0	21.4	41.0	25.0	21.7
Mustard	0.05	16.3	20.6	32.3	54.0	30.8	15.9
	0.10	14.6	27.3	29.3	47.3	29.6	17.1
	0.30	14.0	25.6	24.3	43.2	29.6	20.0
Soybean	0.05	14.6	23.3	29.6	37.0	26.1	20.6
	0.10	12.0	21.6	25.6	34.0	23.3	23.4
	0.30	09.3	14.6	20.6	31.3	18.9	27.8
Neem	0.05	16.3	21.0	29.3	52.6	29.8	16.9
	0.10	13.3	19.0	24.1	46.0	25.6	21.1
	0.30	12.6	17.3	18.6	44.3	23.2	23.5
Citronella	0.05	17.3	26.0	31.6	52.6	31.8	14.9
	0.10	14.3	21.0	29.3	49.0	28.4	18.3
	0.30	00.0	00.0	04.3	19.3	05.9	22.1
Chaulmoogra	0.05	00.6	02.6	09.0	31.0	10.8	35.9
	0.10	00.3	01.5	07.0	26.3	08.7	38.0
	0.30	00.0	00.0	04.3	19.3	05.9	40.8
Clove	0.05	03.6	04.6	15.2	39.6	15.7	31.0
	0.10	02.9	03.6	10.9	36.3	13.4	33.3
	0.30	02.3	03.0	08.3	34.3	11.9	34.8
Control		39.0	43.0	41.0	64.0	46.7	-

Interaction of oils (A) with concentrations (B) and observation days (C)

	(A)	(B)	(C)	AxB	AxC	BxC	AxBxC
S Em ±	0.28	0.16	0.18	0.48	0.56	0.32	0.97
CD at 5%	0.77	0.44	0.49	1.33	1.55	0.88	2.66

Table 37. Efficacy of different vegetative oils on developmental period of *C. chinensis* at every 30 days up to 120 days

OIL	Conc. (v/w) (%)	Mean developmental period (oviposition - adult emergence)					
		30 days	60 days	90 days	120 days	Mean	Day increase over control
Rice bran	0.05	24.3	38.0	43.3	44.0	37.4	0.6
	0.10	24.3	38.6	43.6	45.3	37.9	1.1
	0.30	24.6	38.8	43.6	45.6	38.4	1.6
Niger	0.05	24.6	36.0	44.6	44.6	37.4	0.6
	0.10	24.9	37.0	44.8	44.8	37.8	1.0
	0.30	24.9	37.3	44.8	45.0	38.0	1.2
Mustard	0.05	23.1	38.6	44.3	45.3	37.6	0.8
	0.10	23.3	38.6	44.5	45.3	37.8	1.0
	0.30	23.6	38.7	44.8	45.6	38.1	1.3
Soybean	0.05	25.6	39.3	46.3	48.3	39.8	3.0
	0.10	26.0	41.0	47.0	49.0	40.5	3.7
	0.30	26.6	41.6	47.5	50.3	41.5	4.7
Neem	0.05	25.0	38.7	44.5	46.3	38.5	1.7
	0.10	25.2	38.9	44.9	46.8	38.8	2.0
	0.30	25.4	39.2	45.3	47.3	39.2	2.4
Citronella	0.05	24.1	37.0	45.3	45.3	37.9	1.1
	0.10	24.8	37.6	45.6	45.8	38.4	1.6
	0.30	24.8	38.0	45.8	46.1	39.2	2.6
Chaul moogra	0.05	-	41.3	46.3	47.1	44.6	2.6
	0.10	-	-	46.6	47.6	46.4	2.6
	0.30	-	-	46.8	48.5	46.5	2.9
Clove	0.05	-	39.0	47.3	46.0	44.1	2.4
	0.10	-	39.3	47.6	46.3	44.3	2.6
	0.30	-	39.6	48.0	46.8	44.6	2.7
Control		23.2	37.3	43.5	44.3		

Interaction of oils (A) with concentrations (B) and observation days (C)

	(A)	(B)	(C)	AxB	AxC	BxC	AxBxC
S.Em ±	0.28	0.16	0.18	0.48	0.56	0.32	0.97
CD at 5%	0.77	0.44	0.49	1.33	1.55	0.88	2.66

Table 38. Efficacy of different vegetable oils in suppressing emergence of adult *C. chinensis* at every 30 days up to 120 days

OIL	Conc. (%)	Number of adult emergence / 100 green gram seeds after					
		30 days	60 days	90 days	120 days	Mean	Number decrease over control
Rice bran	0.05	09.3	15.6	19.3	31.0	18.8	9.4
	0.1	08.0	13.0	17.4	28.3	16.6	11.6
	0.3	05.3	11.3	14.6	25.5	14.1	14.1
Niger	0.05	09.6	14.2	18.2	32.6	18.6	9.6
	0.1	07.3	12.5	15.9	28.7	16.1	12.1
	0.3	06.1	09.6	14.2	26.2	14.0	14.2
Mustard	0.05	12.3	16.3	21.4	32.6	20.6	7.6
	0.1	10.0	14.6	19.6	29.7	18.4	9.8
	0.3	08.3	11.9	16.6	27.5	16.0	12.2
Soybean	0.05	08.6	12.6	14.6	25.6	15.3	12.9
	0.1	08.0	11.0	13.0	24.9	14.2	14.0
	0.3	06.0	10.2	11.9	23.2	12.8	15.4
Neem	0.05	08.3	09.0	11.3	24.4	13.2	15.0
	0.1	06.4	08.3	08.3	24.0	11.7	16.5
	0.3	05.3	07.3	07.0	21.5	10.2	18.0
Citronella	0.05	08.9	12.3	13.4	28.0	15.1	13.1
	0.1	07.6	11.9	12.9	24.9	14.3	13.9
	0.3	06.3	10.6	11.6	23.0	12.8	15.4
Chaul moogra	0.05	00.0	00.6	04.6	08.0	03.3	24.9
	0.1	00.0	00.3	03.0	06.0	02.3	25.9
	0.3	00.0	00.0	02.6	04.0	01.6	26.6
Clove	0.05	03.0	07.3	11.4	14.6	9.07	19.1
	0.1	02.2	06.6	08.5	12.6	7.4	20.3
	0.3	01.5	04.3	06.5	11.3	5.9	22.3
Control	27.0	23.0		26.0	37.0	28.2	-

Interaction of oils (A) with concentrations (B) and observation days (C)

	Oil (A)	Concentration (%) (B)	Days after application (C)	A x B	A x C	B x C	A x B x C
SEm ±	0.19	0.11	0.13	0.34	0.39	0.23	0.69
C.D. at 5%	0.52	0.30	0.36	0.94	1.08	0.63	1.91

Fig.25. Efficacy of different plant oils at 0.30 (%) concentrations in suppressing egg laying by *C. chinensis* upto 120 days

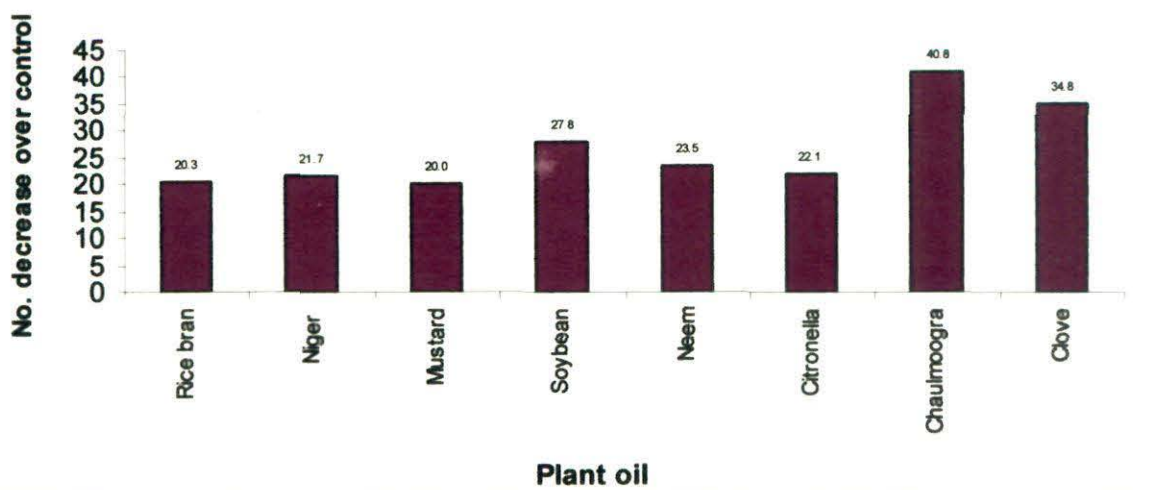


Fig. 26.Efficacy of different plant oils at 0.3(%) cons. in increasing developmental period of *C. chinensis* over control upto 120 days

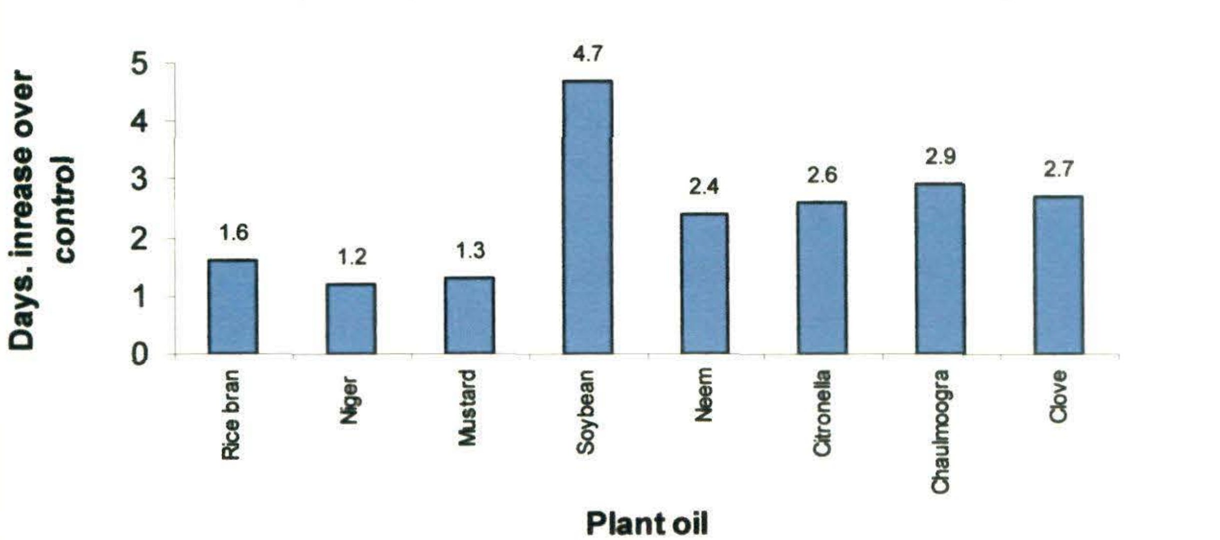


Fig.27. Efficacy of different plant oils at 0.3(%) concentrations in suppressing adult emergence over control of *C. chinensis* upto 120 days