6. OBSERVATIONS AND RESULTS

6.1. Recording of insect groups associated with *Alnus nepalensis:*

Insects were found to use *Alnus nepalensis* as true host, as alternate host, as roost and shelter. Familial list of insects found associated with the shade tree has been provided (Tables 1a-1c). The survey work showed dominance of species (RTU) of Coleoptera (43%) followed by Lepidoptera (19%), Homoptera (16%), Hemiptera (7%), Hymenoptera (5%), Orthoptera (4%), Neuroptera (2%), Thysanoptera (2%) and Diptera (2%), when collections from both the altitudes for all the three years of the study were considered (Fig.3).

Maximum occurrence of the insect species on the tree was found in the spring season (March to May) when new leaves appeared. In spring, most of the insects associated, were the coleopterans, along with a few lepidopterans, hymenopterans, thysanopterans and hemipterans. With the onset of summer, which brought in heavy rains from end of May to September, a number of adult moths, few coleopterans, dipterans and neuropterans became prevalent. In winter, the insects occurred in less proportion. However, the dominance of cicadid species was quite apparent during these months. Along with this, in early winter, caterpillars of two lepidopteran species were also found, one of them (Notodontidae) in abundance.

A number of predators and parasitoids were found associated with *A. nepalensis* attacking the above phytophages as their prey/ host. One

Fig.3. Average proportion of orders of insect associated with *Alnus nepalensis* (Shade tree) at Pangthang and Kabi

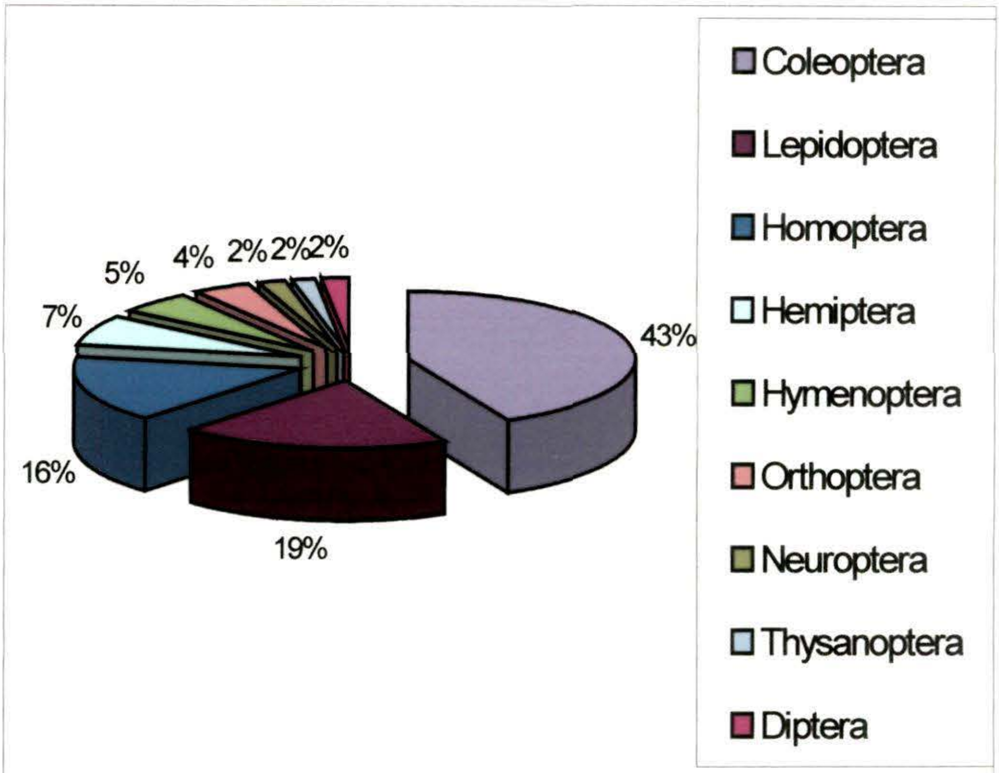


Table: 1a. Insect fauna associated with *Alnus nepalensis* at two altitudes of Sikkim in the Year 2000

		Pangthang (2160m amsl)		Kabi (1630m amsl)	
		No. of species (RTU)	Month of occurrence	No. of species (RTU)	Month of occurrence
Order	**Coleoptera**				
Family	Coccinellidae	7	Jan------Dec	7	Jan-------Dec.
	Scarabaeidae	6	Feb--------Oct.	7	March---Oct.
	Chrysomelidae	6	April------Sept.	6	April------Sept.
	Curcùlionidae	3	Jan.-------March	3	Dec.---March
	Galerucidae	1	Jan.----Dec.	0	Not found
	Buprestidae	2	July-------Oct.	0	Not found
	Cerambycidae	0	Not found	1	July------Sept.
Order	**Lepidoptera**				
Family	Noctuidae	4	May--------Oct.	4	July-------Sept.
	Pyralidae	1	Aug.------Sept.	1	Aug.-------
	Arctiidae	1	April-------Aug.	1	April-------Aug.
	Eupterotidae	1	June------July	1	June------July
	Lymantriidae	1	June---------Aug.	1	May-------July
	Notodontidae	1	Nov.--------May	1	Nov.--------May
Order	**Homoptera**				
Family	Cicadidae	3	Oct.------March	5	Oct.--------Feb.
	Psyllidae	2	July-------Oct.	2	July--------Oct.
	Aphididae	2	Feb.-------Aug.	2	March-----July
	Membracidae	0	Not found	1	Nov.-------Dec.

Table 1a continued.....

Order	**Hemiptera**				
Family	Pentatomidae	3	April-------Sept.	3	May-------July
	Miridae	1	July---------Sept.	1	July-------Sept.
	Coreidae		Not found	2	July-----Aug.
Order	**Hymenoptera**				
Family	Braconidae	1	May-------July	1	May-------July
	Formicidae	3	Feb.---------June	3	March-----Aug.
Order	**Orthoptera**				
Family	Phasmatidae	1	Nov.-------Dec.	1	Nov.-------Dec.
	Mantidae	1	Sept.-------Oct.	1	Sept.-------Oct.
	Tetrigidae	1	Jan.-------Dec.	1	Jan.-------Dec.
Order	**Neuroptera**				
Family	Chrysopidae	1	April------July	1	April------July
Order	**Thysanoptera**				
Family	Thripidae	1	April------Aug.	1	June-------Sept.
Order	**Diptera**				
Family	Tachinidae	1	July------Sept.	1	July------Sept.

Table: 1b. Insect fauna associated with *A. nepalensis* at two altitudes of Sikkim in the Year 2001

		Pangthang (2160m amsl)		Kabi (1630m amsl)	
		No. of species (RTU)	Month of occurrence	No. of species (RTU)	Month of occurrence
Order	**Coleoptera**				
Family	Coccinellidae	7	Jan------Dec.	6	Jan------Dec
	Scarabaeidae	5	Feb-------Oct.	6	March-----Oct.
	Chrysomelidae	7	April------Sept.	6	April----Sept.
	Curculionidae	3	Jan.-------April	3	Dec.--- March
	Galerucidae	1	Jan.----Dec.	1	Jan.----Dec.
	Buprestidae	0	Not found	0	Not found
	Cerambycidae	0	Not found	0	Not found
Order	**Lepidoptera**				
Family	Noctuidae	4	July--------Oct.	4	July-------Oct.
	Pyralidae	1	Aug.------Sept.	2	Aug.----- Sept.
	Arctiidae	1	April------July	1	May-----Aug.
	Eupterotidae	1	June------July	1	June------July
	Lymantriidae	1	July-------Sept.	3	June------Aug.
	Notodontidae	1	Nov.------April	1	Nov.---- April
Order	**Homoptera**				
Family	Cicadidae	5	Oct.------ March	4	Oct.------ Feb.
	Psyllidae	1	July------Sept.	1	July------Sept.
	Aphididae	2	Feb.-------July	2	Feb.-------Aug.
	Membracidae	*0*	Not found	*0*	Not found

Table 1b continued.....

Order	**Hemiptera**				
Family	Pentatomidae	3	April——Sept.	3	May——July
	Miridae	0	Not found	0	Not found
	Coreidae	1	July——Aug.	2	July——Sept.
Order	**Hymenoptera**				
Family	Braconidae	1	May——July	1	May——July
	Formicidae	3	Feb.——June	3	March—Aug.
Order	**Orthoptera**				
Family	Phasmatidae	2	Dec.——Jan.	1	Nov.—— Dec.
	Mantidae	1	Sept.——Oct.	0	Not found
	Tetrigidae	1	Jan.——Dec.	1	Jan.——Dec.
Order	**Neuroptera**				
Family	Chrysopidae	1	June——Aug.	1	June——July
Order	**Thysanoptera**				
Family	Thripidae	1	April——Aug.	1	June——Sept.
Order	**Diptera**				
Family	Tachinidae	1	July——Sept.	1	July—— Sept.

Table:1c. Insect fauna associated with *A. nepalensis* at two altitudes of Sikkim in Year 2002

		Pangthang (2160m amsl)	2002	Kabi (1630m amsl)	
		No. of species (RTU)	Month of occurrence	No. of species (RTU)	Month of occurrence
Order	**Coleoptera**				
Family	Coccinellidae	7	Jan------Dec	6	Jan------Dec
	Scarabaeidae	5	May-----Oct.	6	April-----Oct.
	Chrysomelidae	7	April----Sept.	6	April----Sept.
	Curculionidae	3	Jan.----- March	3	Dec.--- March
	Galerucidae	1	Jan.----Dec.	1	Jan.----Dec.
	Buprestidae	0	Not found	0	Not found
	Cerambycidae	0	Not found	0	Not found
Order	**Lepidoptera**				
Family	Noctuidae	3	June------Oct.	4	July-------Oct.
	Pyralidae	1	Aug.----Sept.	2	Aug.--------Sept.
	Arctiidae	1	April-----July	1	April-----July
	Eupterotidae	1	June------July	1	June------July
	Lymantriidae	3	July-----Sept.	3	July-------Sept.
	Notodontidae	1	Nov.----April		Nov.---- April
Order	**Homoptera**				
Family	Cicadidae	5	Oct.------ Jan.	4	Oct.--------Jan.
	Psyllidae	1	July-----Sept.	1	July-------Sept.
	Aphididae	2	Feb.------June	2	Feb.-------June
	Membracidae	0	Not found	0	Not found

Table 1c continued.....

Order	**Hemiptera**				
Family	Pentatomidae	3	April----Sept.	3	May-------Sept.
	Miridae	0	Not found	0	Not found
	Coreidae	1	July-----Aug.	2	July-----Sept.
Order	**Hymenoptera**				
Family	Braconidae	1	May------July	1	May------July
	Formicidae	3	Feb.----- June	3	March---Aug.
Order	**Orthoptera**				
Family	Phasmatidae	1	Dec.------Jan.	1	Nov.----- Dec.
	Mantidae	1	Sept.-----Oct.	0	Not found
	Tetrigidae	1	Jan.------Dec.	1	Jan.-------Dec.
Order	**Neuroptera**				
Family	Chrysopidae	2	June-----Aug.	2	June------July
Order	**Thysanoptera**				
Family	Thripidae	1	April----Aug.	1	June-----Sept.
Order	**Diptera**				
Family	Tachinidae	1	July-----Sept.	1	July------Sept.

tachinid fly (Diptera) species was found to parasitise lepidopteran larvae. Lacewings were also found predating on eggs of lepidopterans in the summer. Many coccinellids were found predating on the immature stages of coleoptera and aphids. Pentatomid bug was found throughout the spring season preying on larvae of coleopterans. Almost a similar occurrence of the shade tree associates were recorded in all the three years and at both the altitudes excepting representatives of families like, Buprestidae, Cerambycidae and Miridae, which were not found in years 2001 and 2002 (Table 1b-1c). On the other hand, a species of Membracidae (cow bug) that sporadically occurred in the year 2000 in Kabi was not found in Pangthang in the same year and in the subsequent years at both the altitudes (Table 1a-1c). So also, a species of Galerucidae (coleoptera) which was found to occur throughout the year on *A. nepalensis* in Pangthang was not found in Kabi in year 2000 but was found present at both the altitudes in the subsequent years (Table 1a-1c).

6.1.1. Insects common to *Alnus* and large cardamom plants:

A list of insect species found to attack and damage both, cardamom and *Alnus* plants has been presented in Table 1d. Although there were variations in the time of their occurrence, these insects were present in all the three years of observation and at both the altitudes. The insects common to both the plants were: seven species of coleopterans, two species of hairy caterpillars (Lepidoptera), one species of green aphid (Homoptera: Aphididae), one spieces of thrips (Thysanoptera: Thripidae,

Table 1d: Insect species common to *Alnus* (Shade tree) and large cardamom plants

Order	Species
Coleoptera	*Lema nigricollis* Jacoby
	Chrysomela chlorina Maulik
	Basilepta femoratum Jacoby
	Cleorina metallica Lef.
	Miltina balyi (Jac.)
	Cyphicerus alsus Mshl.(Weevil)
	Cerogria quadrimaculata Hope.(Scarab-beetle)
Lepidoptera	*Cyana effracata* hope.
	Pericalia galactina Hoev.
Homoptera	*Neomyzus circumflexus* (Buckton) (Aphid)
	Kolla opponens (Walker) (White cicada)
Orthoptera	*Mazorradia* sp. Boliyar (Grass hopper)
Thysanoptera	Not identified

in det.), one species of grasshopper (Orthoptera) and a species of white Cicada (Homoptera).

6.2. Seasonal incidence of the major folivores:

An ecological investigation to find out the incidence of the major folivores on *A. nepalensis* shade tree was carried out for three consecutive years. It revealed that although the shade tree was continuously attacked by many insects, the maximum injury was done to its foliage by a lepidopteran, *Gazalina chrysolopha* Kollar (Notodontidae) and a coleopteran, *Chrysomela chlorina* Maulik (Chrysomelidae) at different times of the year. The injury caused by other insects to its foliage was negligible in comparison.

6.2.1. Incidence and population of *G. chrysolopha*:

6.2.1.1. At Pangthang (2160m amsl) (Fig. 4a-4c):

During observations on the seasonal incidence of *G. chrysolopha* at Pangthang, the caterpillars were seen from November 1999 till May first week in the year 2000, while in the subsequent years, i.e., 2001 and 2002, they appeared in December of the previous year and were active till April. The adults of the insect, in the year 2000, started appearing in June-July. However, in the year 2001 and 2002 they were active only in July- August.

The observations on the last three instars (as the larvae of the first two instars nibbled only on the debris/very tender leaves found at the base of the shade tree) of *G. chrysolopha* on the shade tree, revealed that the pest started appearing

Fig.4a. Population change of larvae of *Gazalina chrysolopha* in relation to weather parameters (Pangthang, 2000)

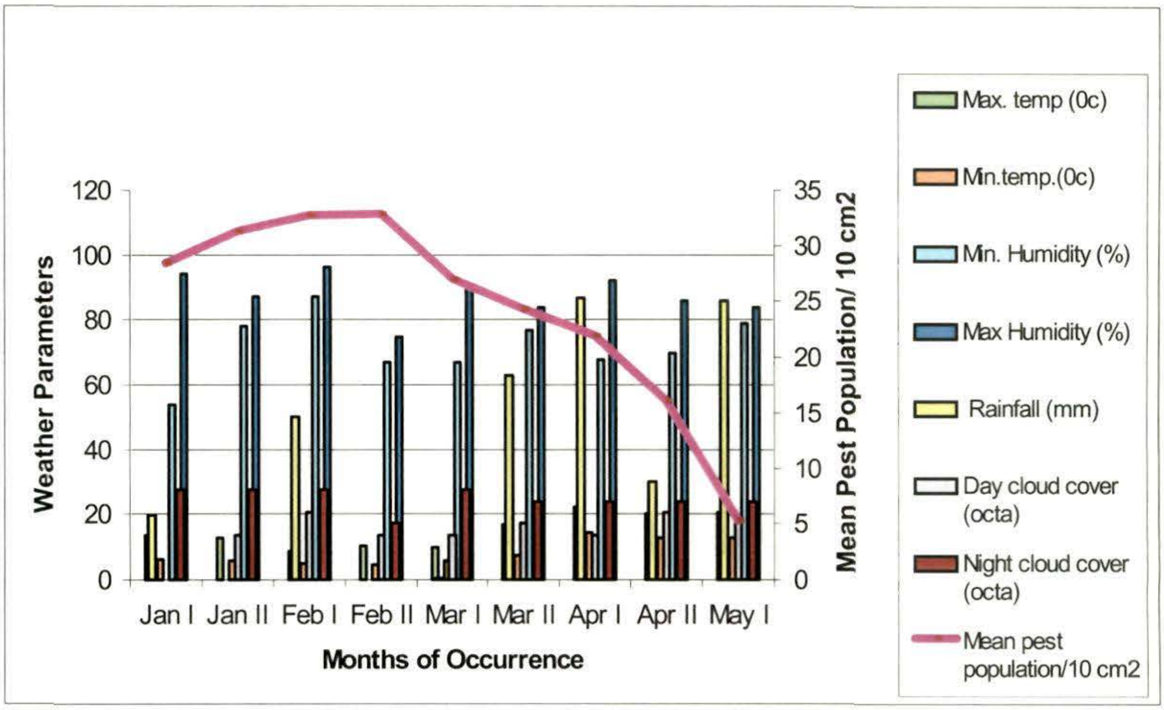


Table: 2a. Relation of population of *G. chrysolopha* larvae with abiotic factors (Pangthang, 2000)

	Weather parameters	Correlation coefficient
Pest population vs	Max. temperature^{0}C	-0.759(*)
	Min. temperature^{0}C	-0.821(**)
	Relative humidity (day)(%)	0.101
	Relative humidity (night)(%)	0.139
	Rainfall(mm)	-0.631
	Cloud cover (day) (Octa)	-0.275
	Cloud cover (night) (Octa)	-0.271

* = Significant at 5% level ** = Significant at 1% level

Fig.4b. Population change of larvae of *G. chrysolopha* in relation to weather parameters (Pangthang, 2001)

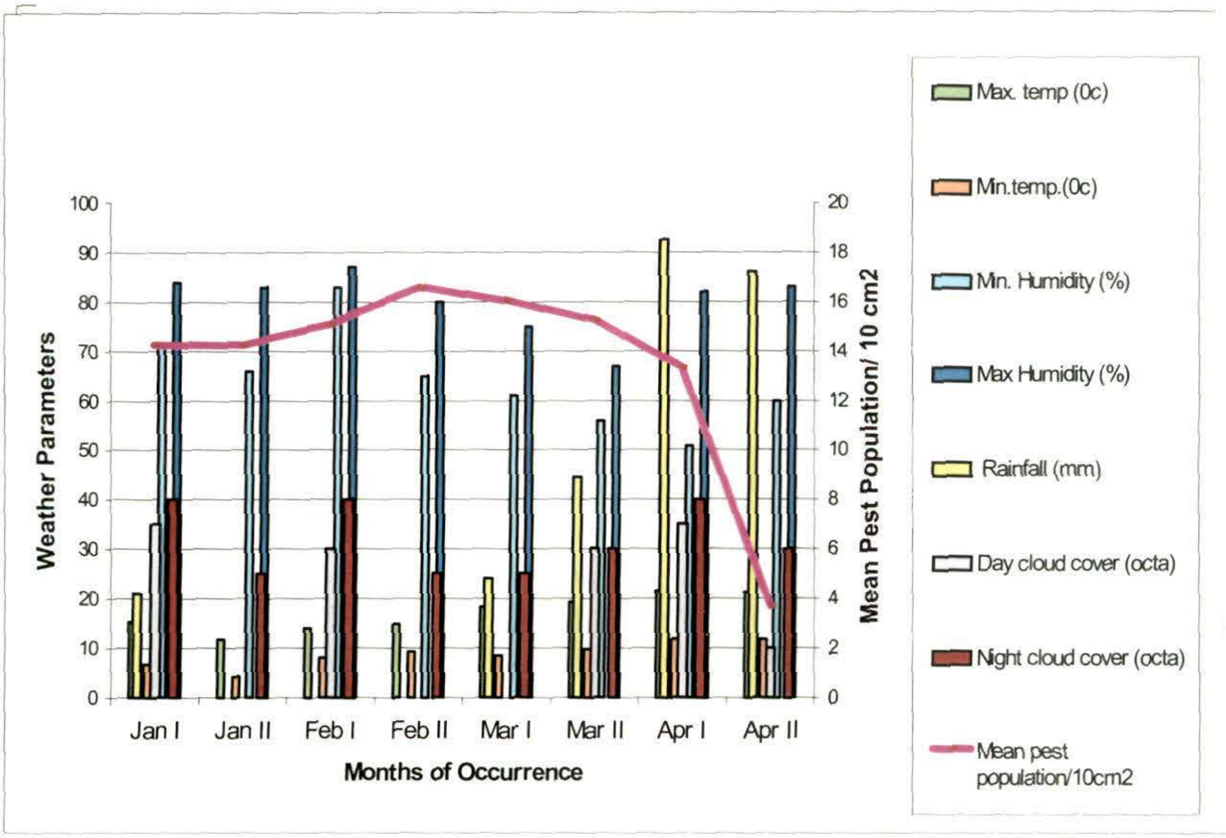


Table: 2b. Relation of population of *G. chrysolopha* larvae with abiotic factors (Pangthang, 2001)

	Weather parameters	Correlation coefficient
	Max. temperature^{0}C	-0.634(**)
	Min. temperature^{0}C	-0.576(*)
	Relative humidity (day)(%)	0.202
Pest population vs	Relative humidity (night)(%)	-0.284
	Rainfall(mm)	-0.730(**)
	Cloud cover (day) (Octa)	-0.085
	Cloud cover (night) (Octa)	-0.159

* = Significant at 5% level ** = Significant at 1% level

Fig.4c. Population change of larvae of *G. chrysolopha* in relation to weather parameters (Pangthang, 2002)

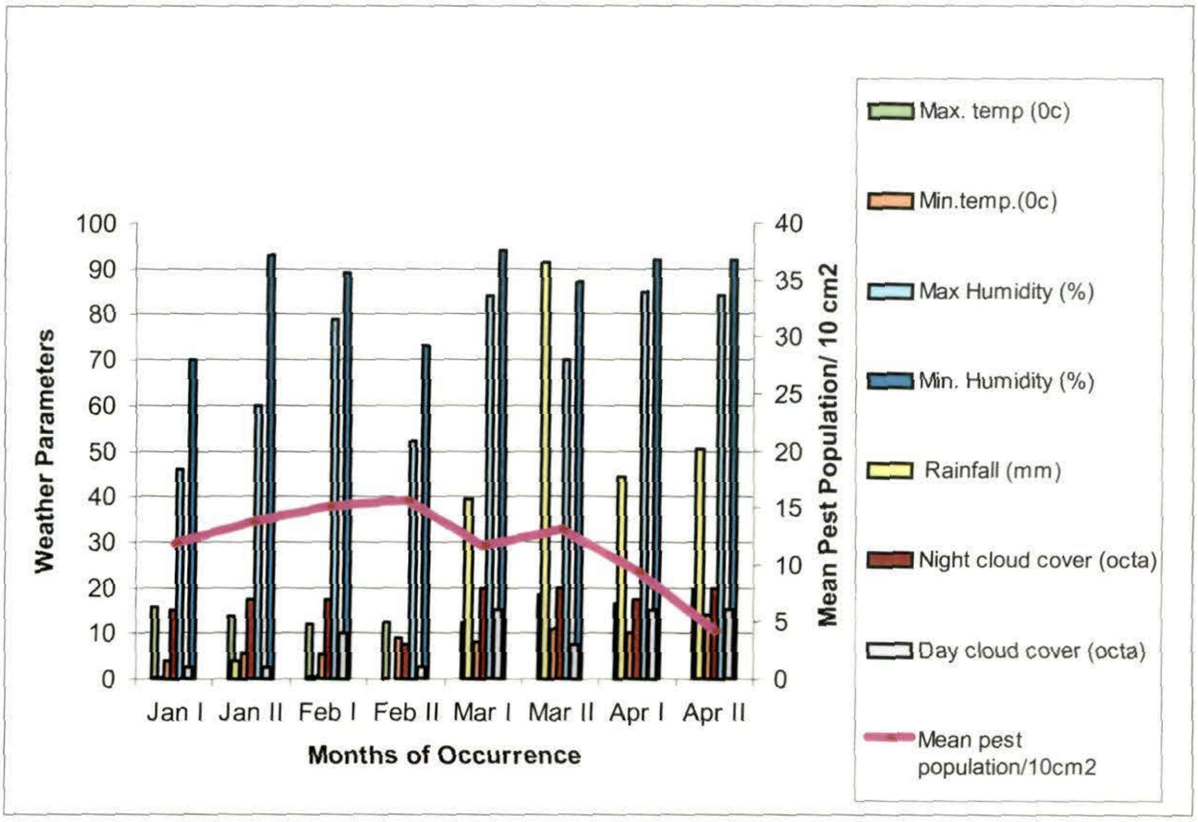


Table: 2c. Relation of population of *G. chrysolopha* larvae with abiotic factors (Pangthang, 2002)

	Weather parameters	Correlation coefficient
Pest population vs	Max. temperature^{0}C	-0.782(*)
	Min. temperature^{0}C	-0.661(**)
	Relative humidity (day)(%)	0.365
	Relative humidity (night)(%)	-0.513(*)
	Rainfall(mm)	-0.639
	Cloud cover (day) (Octa)	-0.65
	Cloud cover (night) (Octa)	-0.511

* = Significant at 5% level ** = Significant at 1% level

in the first week of January in cold weather. As the weather got colder, the population gradually increased. The pest population reached its peak in the second week of February. As the temperature rose, it declined. This trend was observed in all the three years i.e. 2000, 2001 and 2002. An exceptionally high population was observed in the year 2000, which was more pronounced at the peak population period (February to March). Population in the peak period was nearly double than that recorded in the years 2001 and 2002.

6.2.1.1.1. Relations with weather parameters (Table: 2a-2c):

A negative significant correlation between the maximum and minimum temperatures and the pest population was observed in all the three years . A negative significant correlation existed between rainfall received and the population incidence in the year 2001. In all the three years, both day and night cloud cover, showed a negative but non-significant correlation with the pest population. A negative low significance of correlation with the night humidity was, however, observed for the population in the year 2002 (Table 2c).

6.2.1.2. At Kabi (1630m amsl) (Fig. 4d-4f):

The population trend observed at Kabi was, by and large, similar to that at Pangthang. Although, the initial incidence of pest population appeared a little lower at Kabi as compared to Pangthang in the first week of January, it rose gradually resulting in higher population during the peak period i.e. February, in the year 2000. In the years 2001 and 2002,

Fig.4d. Population change of larvae of *G. chrysolopha* in relation to weather parameters (Kabi, 2000)

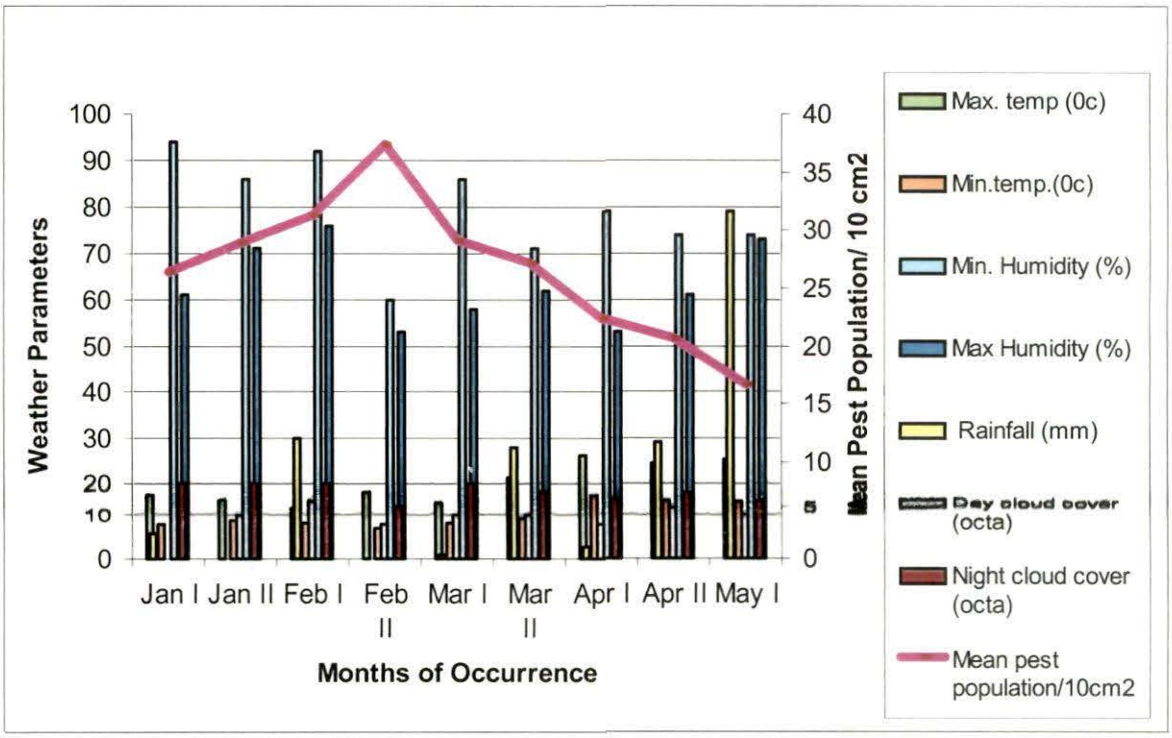


Table: 2d. Relation of population of *G. chrysolopha* larvae with abiotic factors (Kabi, 2000)

	Weather parameters	Correlation coefficient
Pest population vs	Max. temperature^{0}C	-0.766(**
	Min. temperature^{0}C	-0.876(**
	Relative humidity (day)(%)	-0.10
	Relative humidity (night)(%)	-0.38
	Rainfall(mm)	-0.22
	Cloud cover (day) (Octa)	-0.22
	Cloud cover (night) (Octa)	0.02

* = Significant at 5% level ** = Significant at 1% level

Fig.4e. Population change of larvae of *G. chrysolopha* in relation to weather parameters (Kabi, 2001)

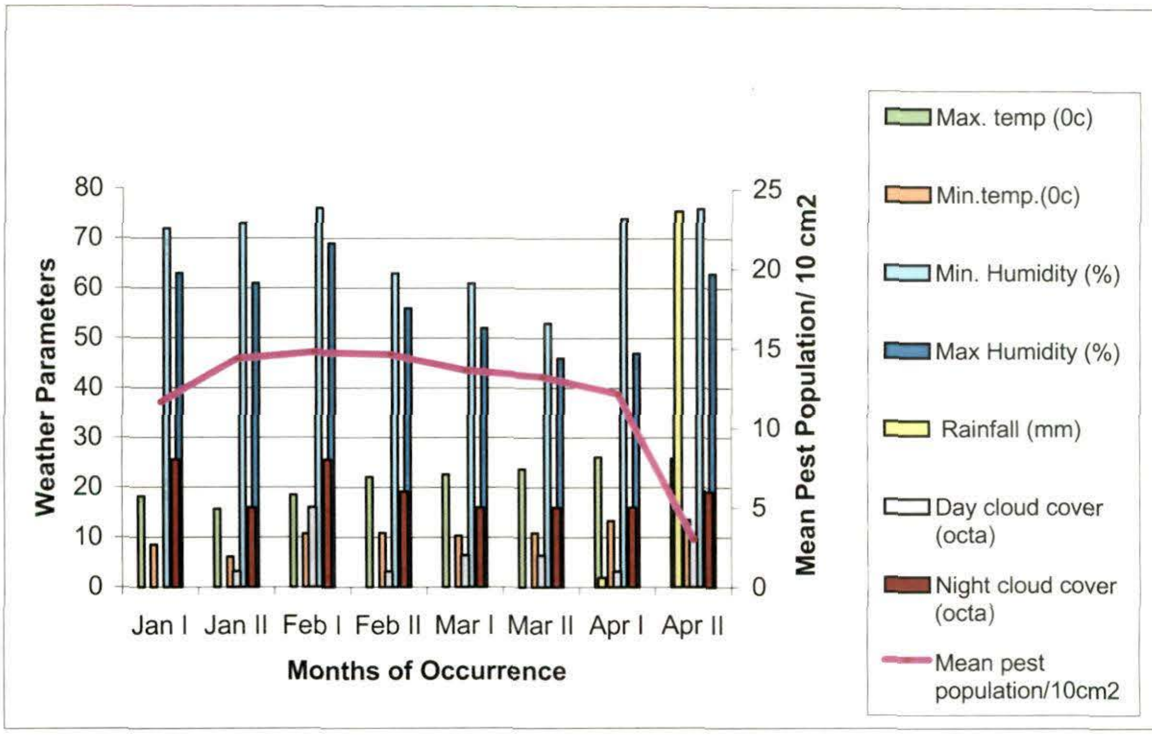


Table: 2e. Relation of population of *G. chrysolopha* larvae with abiotic factors (Kabi, 2001)

	Weather parameters	**Correlation coefficient**
Pest population vs	Max. temperature^{0}C	-0.363
	Min. temperature^{0}C	-0.915(**)
	Relative humidity (day)(%)	-0.510
	Relative humidity (night)(%)	-0.327
	Rainfall (mm)	-0.938(*)
	Cloud cover (day) (Octa)	-0.156
	Cloud cover (night) (Octa)	-0.127

* = Significant at 5% level ** = Significant at 1% level

Fig. 4f. Population change of larvae of *G. chrysolopha* in relation to weather parameters (Kabi, 2002)

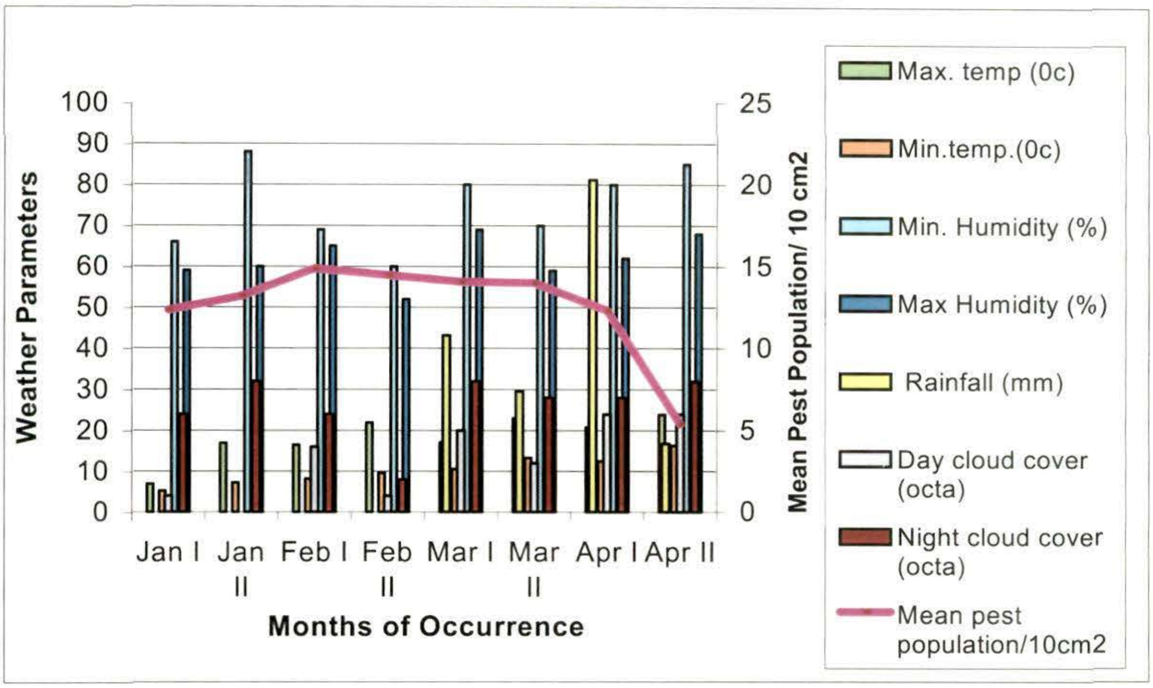


Table: 2f. Relation of population of *G. chrysolopha* larvae with abiotic factors (Kabi, 2002)

	Weather parameters	Correlation coefficient
Pest population vs	Max. temperature ^{0}C	-0.212
	Min. temperature ^{0}C	-0.848(**)
	Relative humidity (day)(%)	0.032
	Relative humidity (night)(%)	0.332
	Rainfall(mm)	0.437
	Cloud cover (day) (Octa)	-0.020
	Cloud cover (night) (Octa)	-0.415

* = Significant at 5% level ** = Significant at 1% level

however, population, in peak period, was lower at Kabi than at Pangthang. The peak period of the pest population remained the same in all the three years i.e. during first and second week of February. The population declined in the following months.

6.2.1.2.1. Relations with weather parameters (Table: 2d-2f):

Maximum and minimum temperatures were found to be having a negative correlation with the pest population. In the year 2000, a negative significant correlation with both minimum and maximum temperature was observed. However, in 2001 and 2002, only minimum temperature was found significantly influencing the pest population. A significant negative correlation between pest population and rainfall was also observed in year 2001. In all the three years, both day and night cloud cover and relative humidity showed a non-significant effect on the pest population.

6.2.2. Incidence and population of *C. chlorina*:

6.2.2.1. At Pangthang (2160m amsl) (Fig. 4g-4i):

Trend of population change of *C. chlorina* was similar in all the three years of study at Pangthang. The first incidence of the pest was observed in the third week of May with very low population. Subsequently, the population increased and attained its peak in the second week of June. Population started declining thereafter and by the end of the fourth week of June, only traces of population remained. This trend continued till the population reappeared in the third week of July

Fig. 4g. Population change of larvae of *Chrysomela chlorina* in relation to weather parameters (Pangthang, 2000)

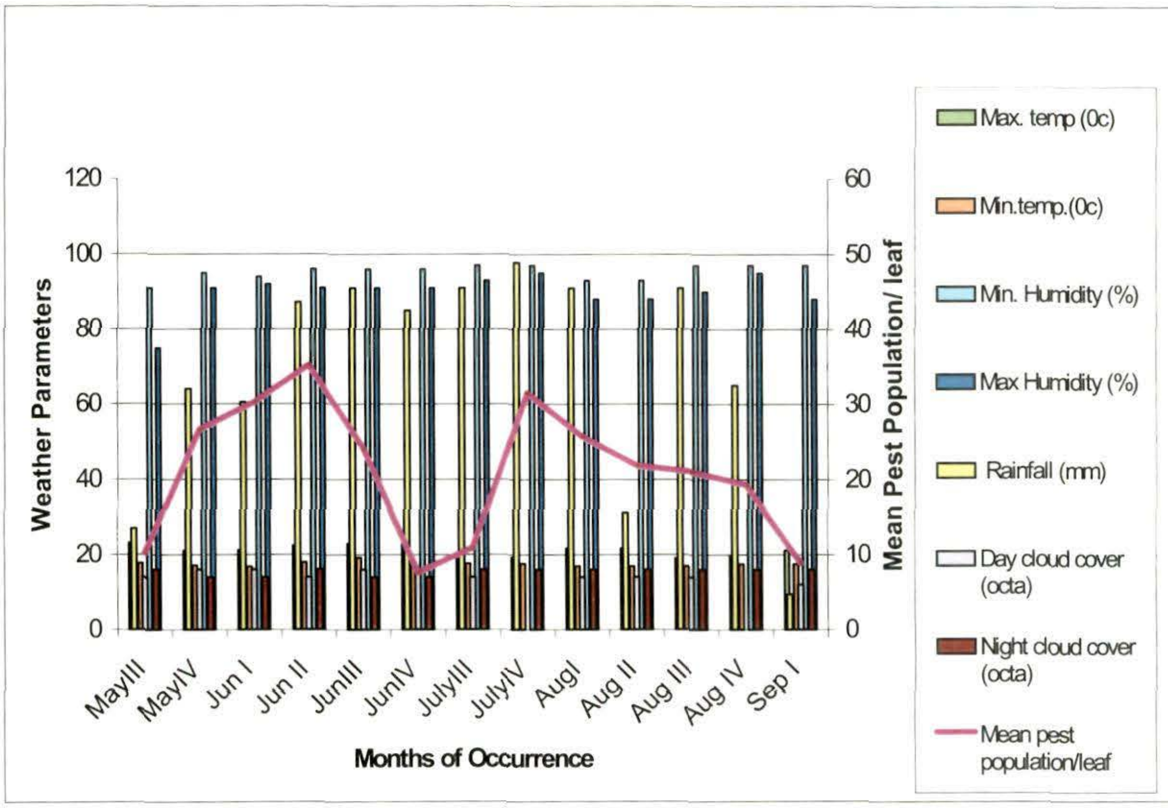


Table: 2g. Relation of population of *C. chlorina* larvae with abiotic factors (Pangthang, 2000)

	Weather parameters	Correlation coefficient
Pest population vs	Max. temperature ^{0}C	0.417
	Min. temperature ^{0}C	0.228
	Relative humidity (day)(%)	0.061
	Relative humidity (night)(%)	-0.279
	Rainfall(mm)	0.610(*)
	Cloud cover (day) (Octa)	0.392
	Cloud cover (night) (Octa)	0.809(**)

* = Significant at 5% level ** = Significant at 1% level

Fig. 4h. Population change of larvae of *C. chlorina* in relation to weather parameters (Pangthang, 2001)

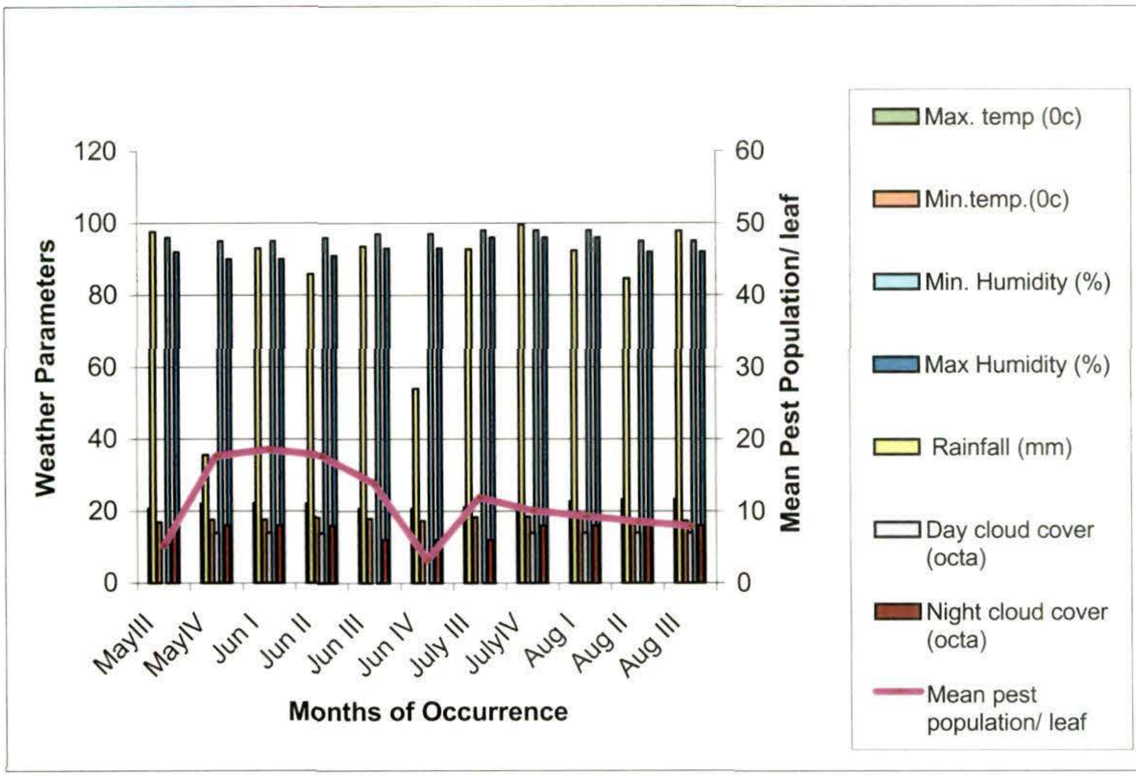


Table: 2h. Relation of population of *C. chlorina* larvae with abiotic factors (Pangthang, 2001)

	Weather parameters	Correlation coefficient
Pest population vs	Max. temperature ^{0}C	0.161
	Min. temperature ^{0}C	0.314
	Relative humidity (day)(%)	-0.272
	Relative humidity (night)(%)	-0.419
	Rainfall(mm)	0.792(**)
	Cloud cover (day) (Octa)	0.620(*)
	Cloud cover (night) (Octa)	0.201

* = Significant at 5% level ** = Significant at 1% level

Fig. 4i. Population change of larvae of *C. chlorina* in relation to weather parameters (Pangthang, 2002)

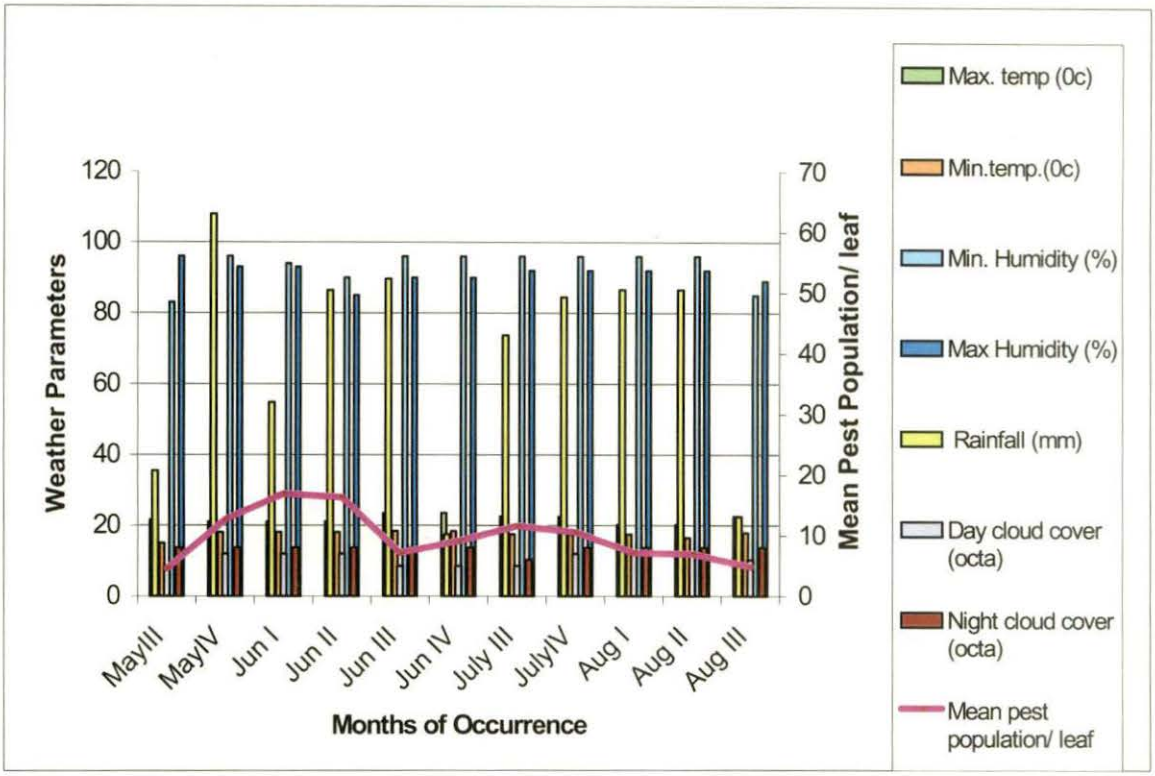


Table: 2i. Relation of population of *C. chlorina* larvae with abiotic factors (Pangthang, 2002)

	Weather parameters	Correlation coefficient
Pest population vs	Max. temperature^{0}C	0.134
	Min. temperature^{0}C	0.542
	Relative humidity (day)(%)	0.449
	Relative humidity (night)(%)	-0.089
	Rainfall(mm)	0.621(*)
	Cloud cover (day) (Octa)	0.014
	Cloud cover (night) (Octa)	0.055

* = Significant at 5% level ** = Significant at 1% level

and attained its second peak in the fourth week of July. The population of *C. chlorina* in the year was quite high in 2000 and continued till September. However, in year 2001 and 2002, the pest disappeared by the third week of August.

6.2.2.1.1. Relations with weather parameters (Table: 2g-2i):

Correlation coefficient between the population and different abiotic factors observed, during the three years, showed that rainfall had positive significant correlation with the pest population in all the three years at Pangthang. In year 2000, night cloud cover showed positive significant correlation with the pest population while in the year 2001, it was the day cloud cover. Relative humidity however, showed non-significant effects. The correlation of temperature and pest population was non-significant.

6.2.2.2. At Kabi (1630m amsl) (Fig. 4j-4l):

At Kabi, the pest appeared in May and continued till August in all the three years. The population trend showed pattern similar to that at Pangthang. Two peaks of the pest population were evident, one in the second week of June and other in the third -fourth week of July.

6.2.2.2.1.Relations with weather parameters (Table: 2j-2l):

The meteorological observations showed significant positive correlation between the pest population and rainfall in all the three years. In the year 2000, significant positive correlation was observed with day cloud cover while in year 2001,it was night cloud cover, which showed it.

Fig. 4j. Population change of larvae of *C. chlorina* in relation to weather parameters (Kabi, 2000)

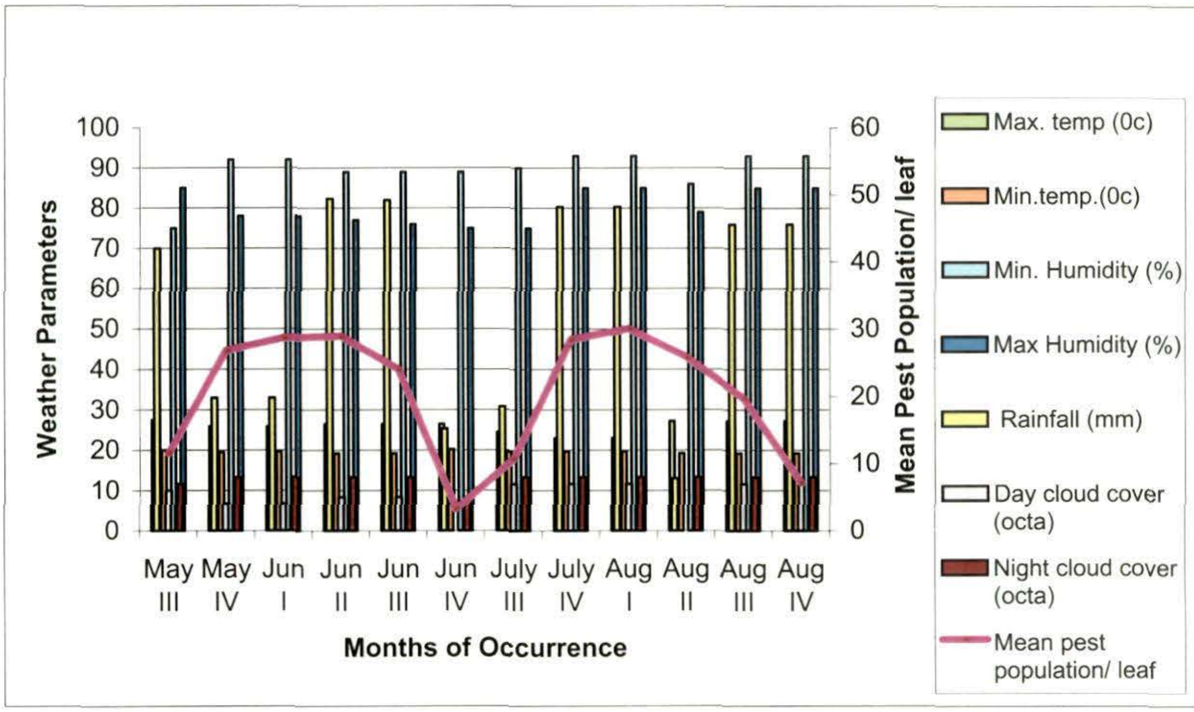


Table: 2j. Relation of population of *C. chlorina* larvae with abiotic factors (Kabi, 2000)

	Weather parameters	Correlation coefficient
Pest population vs	Max. temperature^{0}C	0.594
	Min. temperature^{0}C	0.256
	Relative humidity (day)(%)	0.369
	Relative humidity (night)(%)	-0.176
	Rainfall(mm)	0.613(*)
	Cloud cover (day) (Octa)	*0.616(*)*
	Cloud cover (night) (Octa)	0.572

* = Significant at 5% level ** = Significant at 1% level

Fig.4k. Population change of larvae of *C. chlorina* in relation to weather parameters (Kabi, 2001)

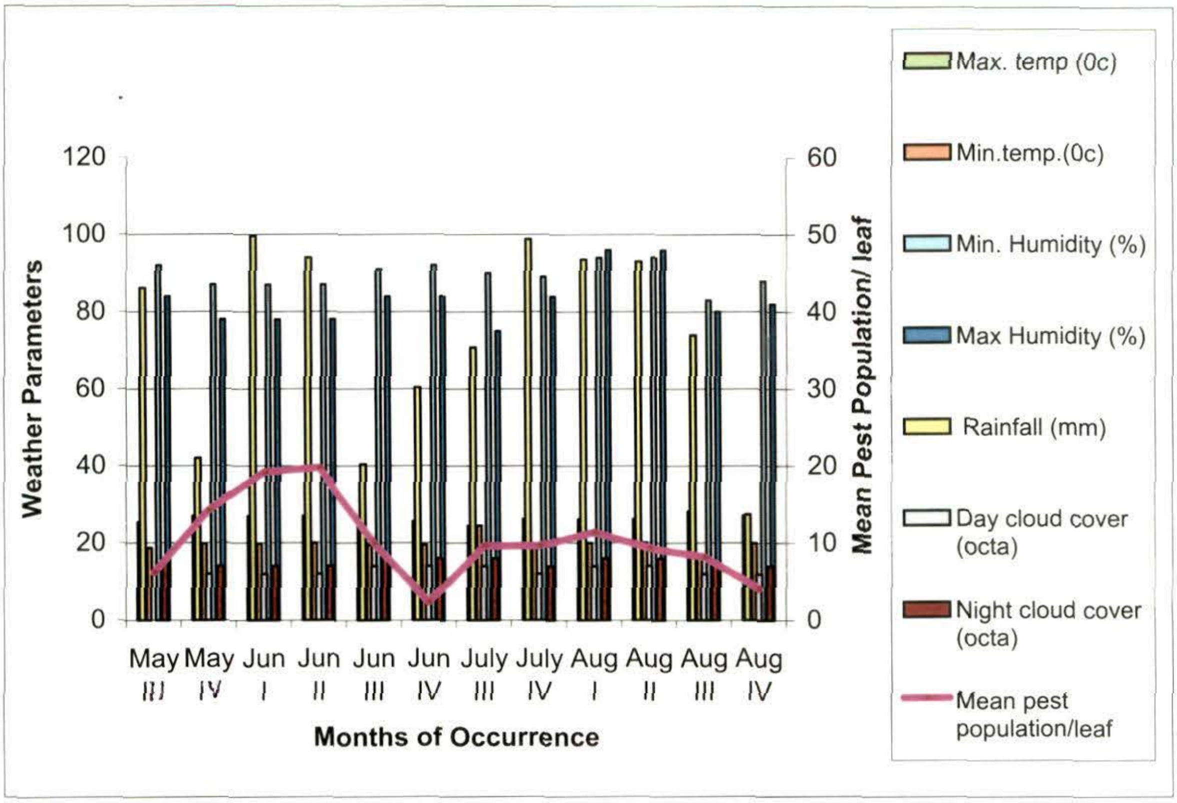


Table: 2k. Relation of population of *C. chlorina* larvae with abiotic factors (Kabi, 2001)

	Weather parameters	Correlation coefficient
Pest population vs	Max. temperature ^{0}C	0.329
	Min. temperature ^{0}C	0.274
	Relative humidity (day)(%)	-0.371
	Relative humidity (night)(%)	-0.368
	Rainfall(mm)	0.849(**)
	Cloud cover (day) (Octa)	0.134
	Cloud cover (night) (Octa)	0.787(**)

* = Significant at 5% level ** = Significant at 1% level

Fig. 4l. Population change of larvae of *C. chlorina* in relation to weather parameters (Kabi, 2002)

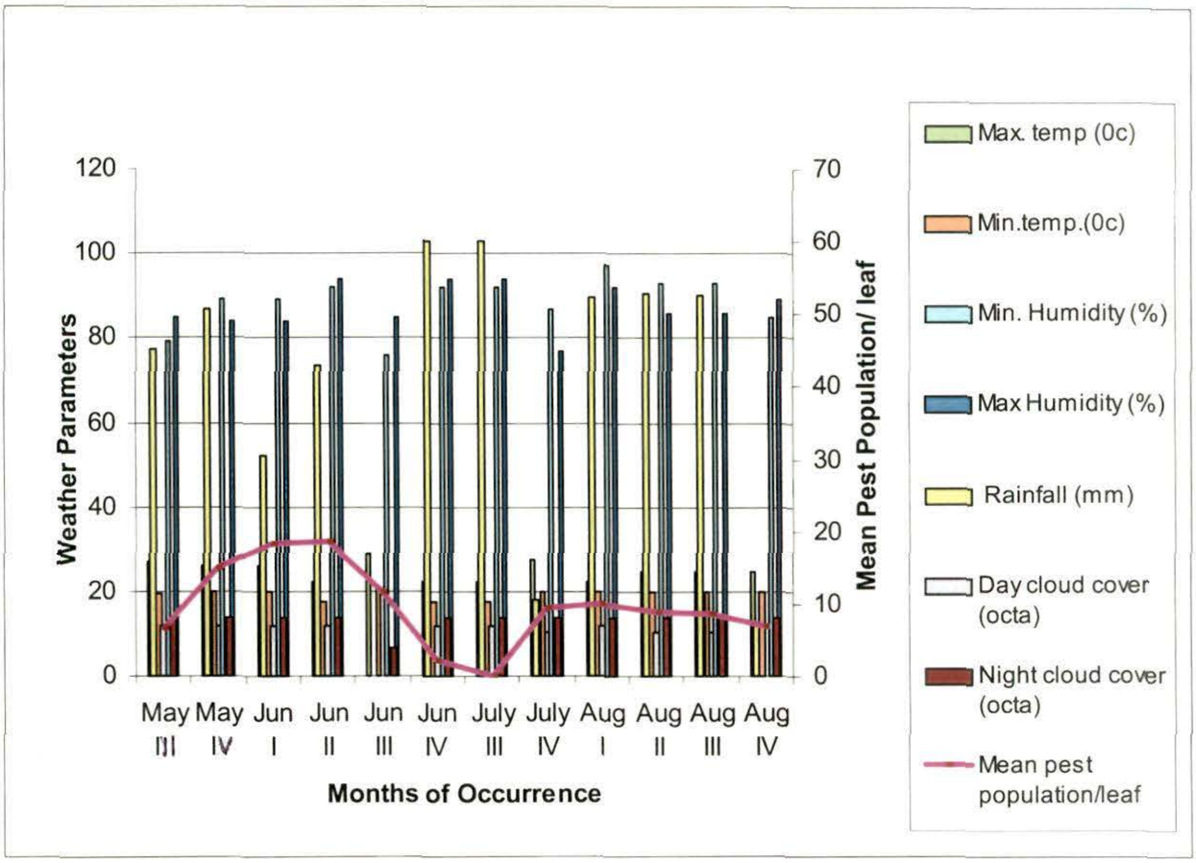


Table:2l. Relation of population of *C. chlorina* larvae with abiotic factors (Kabi, 2002)

	Weather parameters	Correlation coefficient
Pest population vs	Max. Temperature0C	0.285
	Min. Temperature^{0}C	0.277
	Relative humidity (day)(%)	0.026
	Relative humidity (night)(%)	-0.285
	Rainfall (mm)	0.660(*)
	Cloud cover (day) (Octa)	0.168
	Cloud cover (night) (Octa)	0.067

* = Significant at 5% level ** = Significant at 1% level

However, in the year 2002, both day and night cloud cover had non-significant positive correlation with the pest population. Maximum and minimum temperatures showed a positive but non-significant correlation with the pest population in all the three years. Relative humidity had no significant effects on it.

6.3. Life cycle of *G. chrysolopha*:

6.3.1. Egg: Eggs, small sized (0.67 mm in diameter), brown with slight central depression on top. Egg mass covered with brown hair like scales or setae from female body. Hatching (incubation) period about 65 days, percent of hatching almost hundred percent (in laboratory conditions) (Plate 7a).

6.3.2. First and second instar larvae: The 1st and 2nd instar larvae closely resembled one another. Newly emerged larvae, light brown in color, later turned dark; head brown-red with slight depression having a crescent mark. Generally sluggish, body covered with thin light brown hair (Plate 7b). Hair caused irritation and itching. The first and the 2nd instar larvae had similar stadial periods. They fed and nibbled on the debris/very tender leaves (in lab.) found near the base of the tree. Measurements of their head capsule, length and breadth are provided in Table 3a.

6.3.3. Third, fourth and fifth instar larvae:

The 3rd, 4th and 5th instar larvae resembled one another except for their measurements (Plates 7c, 7d, 7e). Head deep red, having slight depression with a crescent mark. Newly moulted larvae dark brown, tufts of long pale brown hair on

Plate 7a. Eggs of *G. chrysolopha* covered with hair released by female moth

Plate 7b. Early instar larvae of *G. chrysolopha*

Plate 7c. Third instar larvae of *G. chrysolopha*

plate - 7a

plate - 7b

plate - 7c

Table 3a. Morphological data of *G. chrysolopha* on *A. nepalensis*

Particulars/Stages	Measurements (mm)
Egg	
(a) Length	0.67 ± 0.050
(b) Width	0.67 ± 0.050
1stinstar larva	
(a) Length	1.69 ± 0.081
(b) Width	0.33 ± 0.015
(c) Width of the head capsule	0.33 ± 0.012
2ndinstar larva	
(a) Length	3.55 ± 0.176
(b) Width	0.61 ± 0.065
(c) Width of the head capsule	0.63 ± 0.039
3rd instar larva	
(a) Length	15.70 ± 0.073
(b) Width	2.50 ± 0.042
(c) Width of the head capsule	1.18 ± 0.019
4th instar larva	
(a) Length	26.10 ± 0.588
(b) Width	4.50 ± 0.125
(c) Width of the head capsule	2.46 ± 0.019
5th instar larva	
(a) Length	35.50 ± 0.677
(b) Width	5.95 ± 0.159
(c) Width of the head capsule	3.00 ± 0.024
Pupa	
(a) Length	22.5 ± 0.215
(b) Width	12.05 ± 0.115
Adult Moth	
1.Male	
(a) Length	24.00 ± 0.789
(b) Width	15.00 ± 0.635
(C) Wing Expanse	36.00 ± 1.15
2.Female	
(a) Length	24.50 ± 0.778
(b) Width	8.50 ± 0.645
(C) Wing Expanse	36.50 ± 1.18

Mean values of 10samples with SD

Plate 7d. Late instar larvae of *G. chrysolopha*

Plate 7e. Late instar larvae of *G. chrysolopha* in resting position

Plate 7f. Pupa of *G. chrysolopha*

plate - 7d

plate - 7e

plate - 7f

back along with a dorsal series of short fulvous tuft. Five pairs of prolegs on III-VI and X segments.

The 3rd, 4th and 5th instar larvae were very active and climbed tall trees at night for food. In the field, the later instars (3rd, 4th, 5th) of *G. chrysolopha,* showed nocturnal movement (migration) in procession. On disturbance, they vomited a dark green fluid. They secreted a white sticky fluid while climbing up and built a silken cover (web) at the base of the tree to rest during daytime. The 4th and 5th instar larvae took almost the same time (30-35 days) to complete their respective stadial periods. Measurements of width of their head capsule and length and breadth of body are provided in Table 3a.

It was observed that the width of head capsule and the length of the *G. chrysolopha* larvae grew in regular geometrical progression. The growth of head width of *G. chrysolopha* was observed to fall into five distinct classes each indicating an instar (Fig.5a).

6.3.4. Pupa: Brown, covered by silken cocoon and very fine and thin hair (Plate 7f). Pupation took place in the debris found at the base of the tree. Measurement of pupa and duration of pupal stage, are provided in Table 3a, 3b.

6.3.5. Adult:

Male (Plate 7g)**:** Male moths white in colour, head and thorax white, legs black, shaft of antennae black, palpi very minute, antennae plumose with long setae, abdomen black with white fringed segments. Fore and hind

Fig: 5a. Relation between progressing width of head capsule and length of the larvae of *G. chrysolopha*

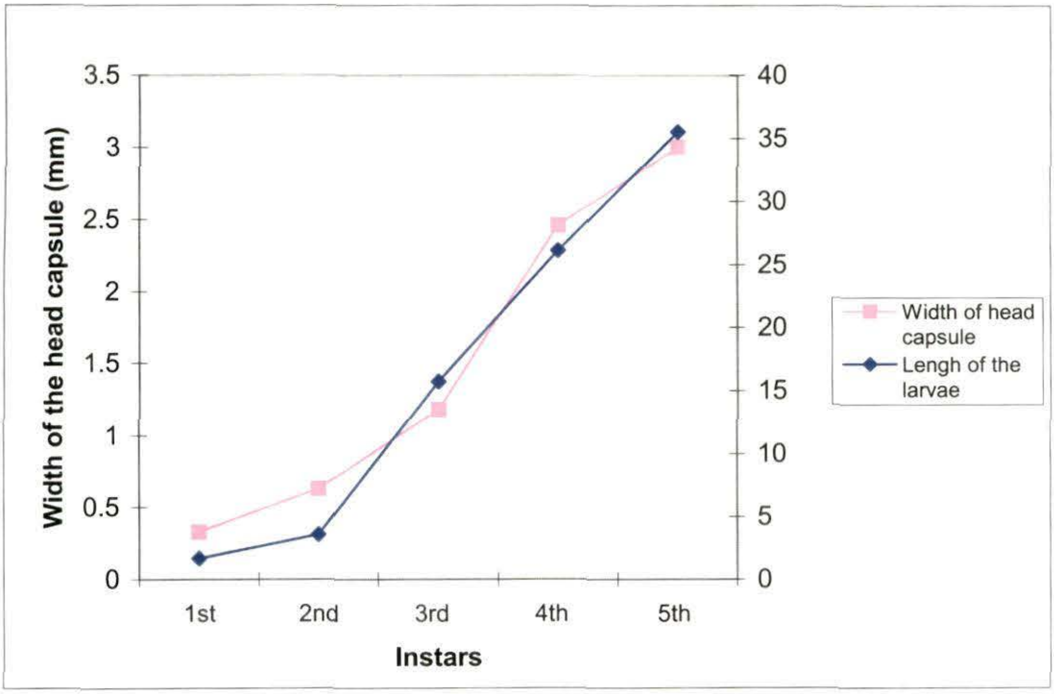


Plate 7g. Adult (Male) of *G. chrysolopha*

Plate 7h. Adult (Female) of *G. chrysolopha*

Plate 7i. Parasitoid pupa emerging from the larva of *G. chrysolopha*

plate - 7g

plate - 7h

plate - 7i

wings white with black veins. Wing expanse of male moth measured 36.00 ± 0.15 mm. Male lived longer than female (Table 3b).

Female (Plate 7h)**:** Females similar to males, but their abdominal segment less fringed, large fulvous anal tuft, barbed setae in anal tuft. Segmental white fringes of abdomen narrower in females. Female wing expanse measured 36.50 ± 0.18 mm. Female released setae of anal tuft over the eggs (Plate 7a), which was carried easily by the wind.

6.3.6. Fecundity and oviposition: Female laid eggs once or sometimes twice in life -time. Mating took place two to three days after emergence. Female moth laid eggs in clusters, piling on and glued to one another in a horizontal pattern. The total number of egg laid/female was 150-250 with an average of 230 eggs. Eggs were generally laid at night on the dorsal side of the leaves and were covered by abdominal hairs released by female moth. In fields, they were also found deposited on the trunk of trees, nearby walls and the light poles. Duration of premating, preovipositing and ovipositing periods are provided in Table 3b. No significant difference was observed in the life cycle pattern and development performance in all the three years of study.

6.3.7. Natural enemies associated with *G. chrysolopha*:

In the fields the eggs of *G. chrysolopha* were predated by lacewings. Attack by ants (*Crematogester* sp.) was also seen. Maximum parasitism was observed in the larval stages of the insect. Larvae of a tachinid fly parasitised late instar larvae of *G. chrysolopha* (Plate7i-7j).

Table 3b. Duration (mean ±SD) of different stages of life cycle of *Gazalina chrysolopha* on *Alnus nepalensis*

Stages	Average (Days)
Premating period	3.50 ± 0.69
Preoviposition period	3.20 ± 0.70
Oviposition period	1.50 ± 0.15
Incubation period	65.50 ± 4.25
Larval periods	
1st instar larva	20.85 ± 1.65
2nd instar larva	22.55 ± 2.24
3rd instar larva	25.50 ± 3.25
4th instar larva	32.96 ± 2.76
5th instar larva	30.61 ± 4.15
Total larval period	165.50 ± 8.59
Pupa	35.50 ± 3.54
Longevity of adults	
(a) Male	7.50 ± 0.15
(b) Female	5.50 ± 0.42
Total life cycle (Egg-Adult)	265.50 ± 8.25

Mean values of 10 samples

Plate 7j. Parasitoid of *G. chrysolopha* (Tachinid fly and its pupa)

plate -7j

In the field, the larvae of *G. chrysolopha* ate the eggs of the tachinid fly along with the leaves of the host tree leading to their infestation. The pupa of the parasitic fly mostly emerged rupturing the body of the host larva (*G. chrysolopha*) resulting in the latter's death. Much more parasitism was observed in the year 2000 as compared to 2001 and 2002. Parasitisation by above-mentioned fly seemed to be a major factor in regulation of the natural population of *G. chrysolopha.*

6.4. Life cycle of *C. chlorina*:

6.4.1. Egg: Eggs oblong, blackish green, measuring 1.95 mm in length and 0.50mm in breadth. Incubation time 3 or 4 days. Hatching success 95% in laboratory conditions (Plate 8a,Tables 4a, 4b).

6.4.2. Larva: The beetle passed through 4 larval instars. The instars showed similarity with one another (Plate 8b-8c).

6.4.3. First Instar: First instar larva very soft, black in colour, generally sluggish, about 1. 95± 0.198 mm in length. Head, antennae, legs, thorax and abdomen black in color. The first instar larvae nibble the green tissue of the leaf.

6.4.4. Second Instar: Body soft and black, larger than 1st instar, 2.55 ± 0.174 mm in length. Stadial period 3 to 4 days. Active feeders of leaf tissue.

6.4.5. Third Instar: Body soft and black, active feeder, moved fast, 3.58 ± 0.214 mm in length. Stadial period 3 to 4 days.

Plate 8a. Eggs of *Chrysomela chlorina*

Plate 8b. Larvae of *C. chlorina* feeding on *A. nepalensis* leaf

Plate 8c. Different stages of *C. chlorina* (showing larvae and pupa)

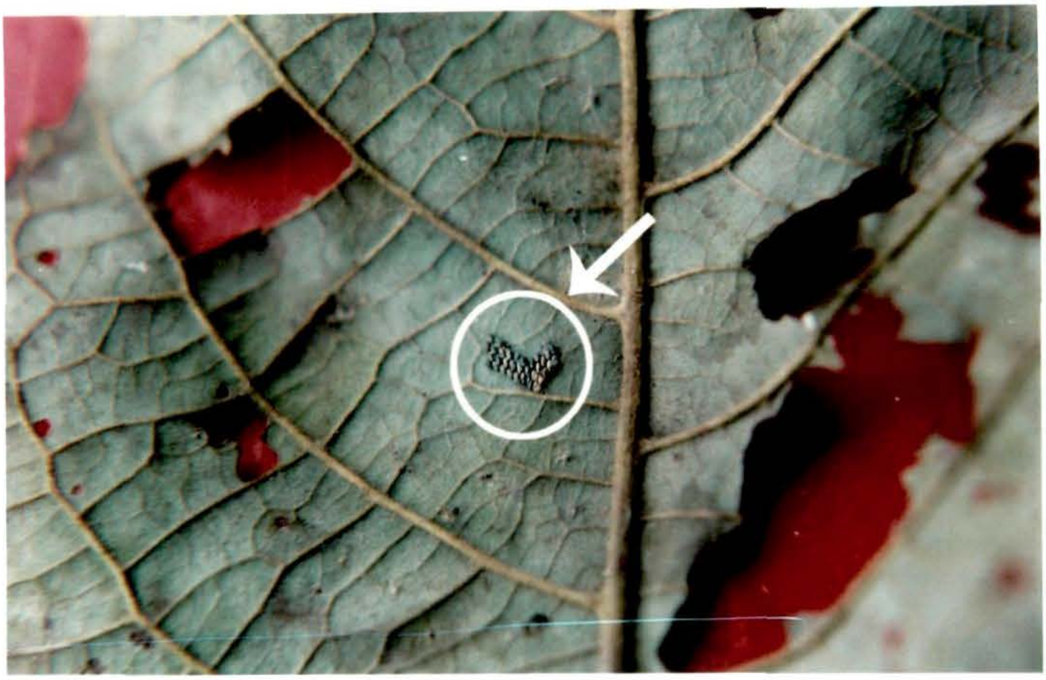


plate - 8a

plate - 8b

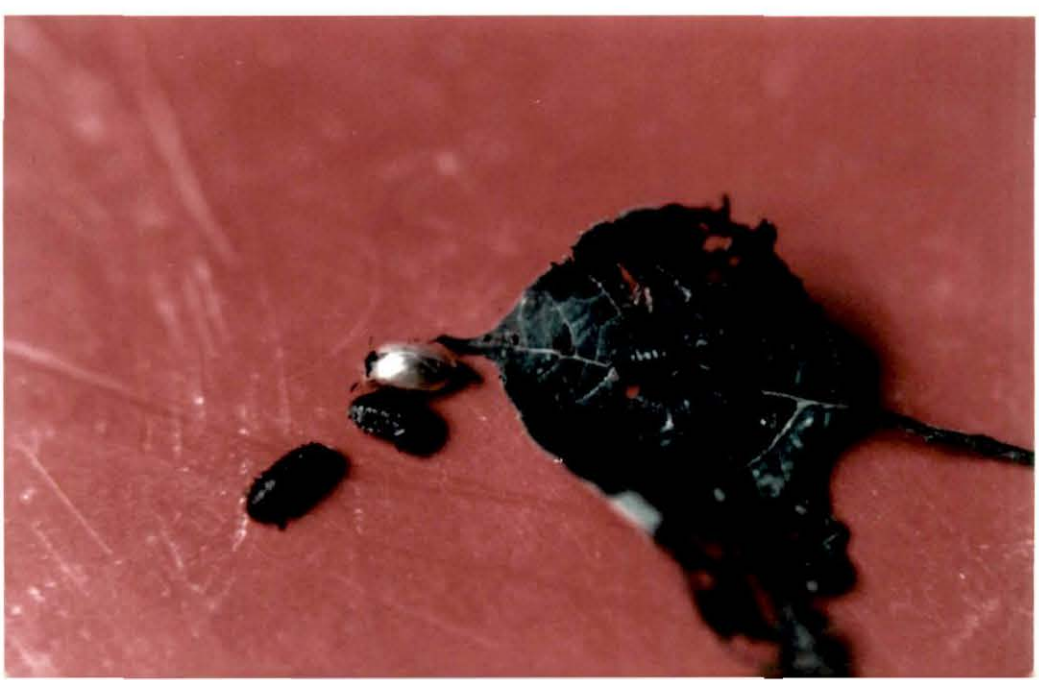


plate - 8c

Table: 4a. Morphometric data of *C. chlorina* on *A. nepalensis*

Particulars/Stages	Measurements (mm)
Egg	
(a) Length	1.95 ± 0.085
(b) Width	0.50 ± 0.055
1st instar larva	
(a) Length	1.59 ± 0.198
(b) Width	1.33 ± 0.112
(c)Width of the head capsule	0.5 ± 0.0090
2nd instar larva	
(a) Length	2.55 ± 0.174
(b) Width	1.61 ± 0.111
(c) Width of the head capsule	0.90 ± 0.096
3rd instar larva	
(a) Length	3.58 ± 0.214
(b) Width	1.70 ± 0.185
(c) Width of the head capsule	1.30 ± 0.019
4th instar larva	
(a) Length	5.50 ± 0.288
(b) Width	2.02 ± 0.085
(c) Width of the head capsule	1.80 ± 0.021
Pupa	
(a) Length	6.05 ± 0.315
(b) Width	1.90 ± 0.115
Adult Beetle	
1.Male	
(a) Length	6.32 ± 0.615
(b) Width	3.50 ± 0.239
2.Female	
(a) Length	6.50 ± 0.695
(b) Width	4.00 ± 0.316

Mean values of 10 samples with SD

6.4.6. Fourth Instar: Body black, very active, prominent abdominal segments, hard body. Feigned death by folding legs. 5.50 ± 0.288 mm in length, stadial period 4 to 5 days.

It was observed that the width of head capsule and the length of the larvae of *C. chlorina* showed a regular geometrical progression. The growth of head width of *C. chlorina* was observed to fall into four distinct classes each indicating an instar (Fig.5b).

6.4.7. Pupa: The fourth instar larva stopped feeding, became hard and inactive and formed pale white membranous puparium (Plate 8c). The length of the pupa measured 6.05 ± 0.315 mm.

6.4.8. Adult: There was no sharp diamorphism between the male and female beetle. Body oblong; broad posteriorly, elytra metallic green with bronzy purple sheen. Prothorax broader than long, pronotum brown with five small rounded spots. Scutellum with rounded apex. Head broad and depressed in the middle, clypeus well marked by two deeply impressed oblique lines meeting at a point in the depressed central area. Antennae short, shining brown black. Abdomen, legs light brown. Male smaller than female. Mating took place within three- four days of adult emergence. When disturbed, adult feigned death by folding legs and lying motionless for certain time. *C. chlorina* completed two to three generations in a year and underwent dormancy in cold winter months (Plate 8d).

Fig: 5b. Relation between progressing width of head capsule and length of the larvae of *C. chlorina*

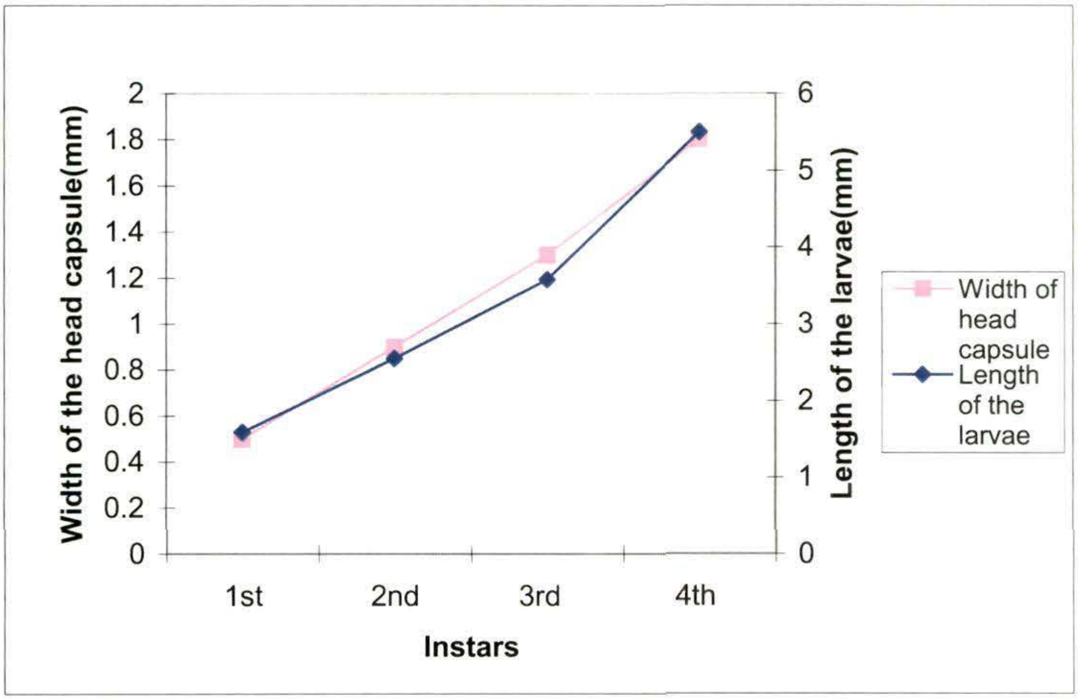


Plate 8d. Adult beetle of *C. chlorina*

plate - 8d

6.4.9. Fecundity and oviposition: Adult female started laying eggs within a few hours of mating. A single female laid up to twenty five to thirty eggs at a time. Female laid eggs two to three times during life time. Eggs were laid on the dorsal side of the leaf, on stem in a cluster. Duration of premating period, preovipositing and ovipositing periods are provided in Table 4 b. No significant difference was observed in the life cycle pattern and development- performance in all the three years of study.

6.4.10. Natural enemies associated with *C. chlorina*:

In the fields, mainly the pentatomid bugs attacked the eggs of *C. chlorina*. The first instar larvae of the coccinellid, *Aiolocaria hexaspilota,* were found feeding on the egg masses of the pest. The larvae of *C. chlorina* were predated by the adults and the late instar larvae of *A. hexaspilota* that occurred concurrently having a life cycle pattern coinciding with that of *C. chlorina*. It appeared that this predator was the main factor in controlling the pest population. Other predators, such as *Harmonia eucharis* and *H. sedecimnotata* were very few in number and only occasionally fed on the grubs. Both the above mentioned predators were found only at Pangthang in year 2000 and 2001. At Kabi they were seen attacking the pest only in the year 2000. In year 2002, they were not seen at either of these two altitudes.

Table: 4b. Duration (mean ±SD) of different stages of life cycle of *C. chlorina* on *A. nepalensis*

Particulars/Stages	Duration (days)
Pre mating period	3.50 ± 1.044
Oviposition period	5.50 ± 1.086
Incubation period	3.50 ± 2.150
Larval periods	
1st instar larva	3.50 ± 0.710
2nd instar larva	3.00 ± 0.425
3rd instar larva	4.50 ± 0.705
4th instar larva	4.50 ± 0.500
Total larval period	15.50 ± 2.540
Pupa	3.50 ± 0.555
Longevity of adults	
(a) Male	9.50 ± 1.450
(c) Female	8.50 ± 1.150
Total life cycle (Egg-Adult)	38.50 ± 2.250

Mean values of 10samples

6.5. Survivorship study of *G. chrysolopha* (Fig 6a):

The survivorship curve of *G. chrysolopha* showed no mortality in the first week followed by marginal mortality rate till 28th day. After that larvae, in general, had very less mortality till the 144th day. From 148th day (with some variations), death rate, in general, increased and it reached its maxima on the 160th day or in the last few days of its larval life. Generally the death took place during moulting. l_x value for larval survival ultimately showed that the number of larvae entering into pupation was quite high (Table 5a).

The survivorship curve of *G. chrysolopha* appeared to stand between curves Type I and II as suggested by Pearl (1928).

6.6. Survivorship study of *C. chlorina* (Fig 6b):

Observations made on the survivorship of *C. chlorina,* revealed that there was a gradual increase in mortality of the grubs till the 4th day. Following this, an enhanced mortality but with some variations was observed. This trend continued till 21st day. An increase in the death rate was observed from 22nd day, which continued till all the larvae entered pupation (Table 5b). Generally, maximum death took place during moulting.

The survivorship curve of *C. chlorina* appeared to stand between curves Type I and II as suggested by Pearl (1928).

Table: 5a.Survivorship table of *G. chrysolopha*

X	l_x	d_x	L_X	T_X	e_x	1000 (q_x)
0	1000	0	1000.0	27433.0	27.433	0.000
4	1000	2	999.0	26433.0	26.433	2.000
8	998	0	998.0	25434.0	25.485	0.000
12	998	68	964.0	24436.0	24.485	68.136
16	930	2	929.0	23472.0	25.239	2.151
20	928	10	923.0	22543.0	24.292	10.776
24	918	8	914.0	21620.0	23.551	8.715
28	910	160	830.0	20706.0	22.754	175.824
32	750	20	740.0	19876.0	26.501	26.667
36	730	10	725.0	19136.0	26.214	13.699
40	720	2	719.0	18411.0	25.571	2.778
44	718	0	718.0	17692.0	24.641	0.000
48	718	13	711.5	16974.0	23.641	18.106
52	705	6	702.0	16262.5	23.067	8.511
56	699	29	684.5	15560.5	22.261	41.488
60	670	1	669.5	14876.0	22.203	1.493
64	669	9	664.5	14206.5	21.235	13.453
68	660	9	655.5	13542.0	20.518	13.636
72	651	11	645.5	12886.5	19.795	16.897
76	640	2	639.0	12241.0	19.127	3.125
80	638	2	637.0	11602.0	18.185	3.135
84	636	15	628.5	10965.0	17.241	23.585
88	621	1	620.5	10336.5	16.645	1.610
92	620	0	620.0	9716.0	15.671	0.000
96	620	2	619.0	9096.0	14.671	3.226
100	618	4	616.0	8477.0	13.717	6.472
104	614	0	614.0	7861.0	12.803	0.000
108	614	0	614.0	7247.0	11.803	0.000
112	614	4	612.0	6633.0	10.803	6.515
116	610	2	609.0	6021.0	9.870	3.279
120	608	0	608.0	5412.0	8.901	0.000
124	608	0	608.0	4804.0	7.901	0.000
128	608	2	607.0	4196.0	6.901	3.289
132	606	2	605.0	3589.0	5.922	3.300
136	604	0	604.0	2984.0	4.940	0.000
140	604	0	604.0	2380.0	3.940	0.000
144	604	72	568.0	1776.0	2.940	119.205
148	532	10	527.0	1208.0	2.271	18.797
152	522	202	421.0	681.0	1.305	386.973
156	320	220	210.0	260.0	0.813	687.500
160	100	100	50.0	50.0	0.500	1000.000

X= age in days, l_x = observed number of larvae surviving at start of X age interval, d_x =number dying during age interval x, L_X = number of individuals alive between ages x and x+1, T_X = individuals x time unit, e_x =expectation of life remaining for individuals of age x, q_x = mortality rate for an age interval.

Fig 6a. **Survivorship curve of *G. chrysolopha***

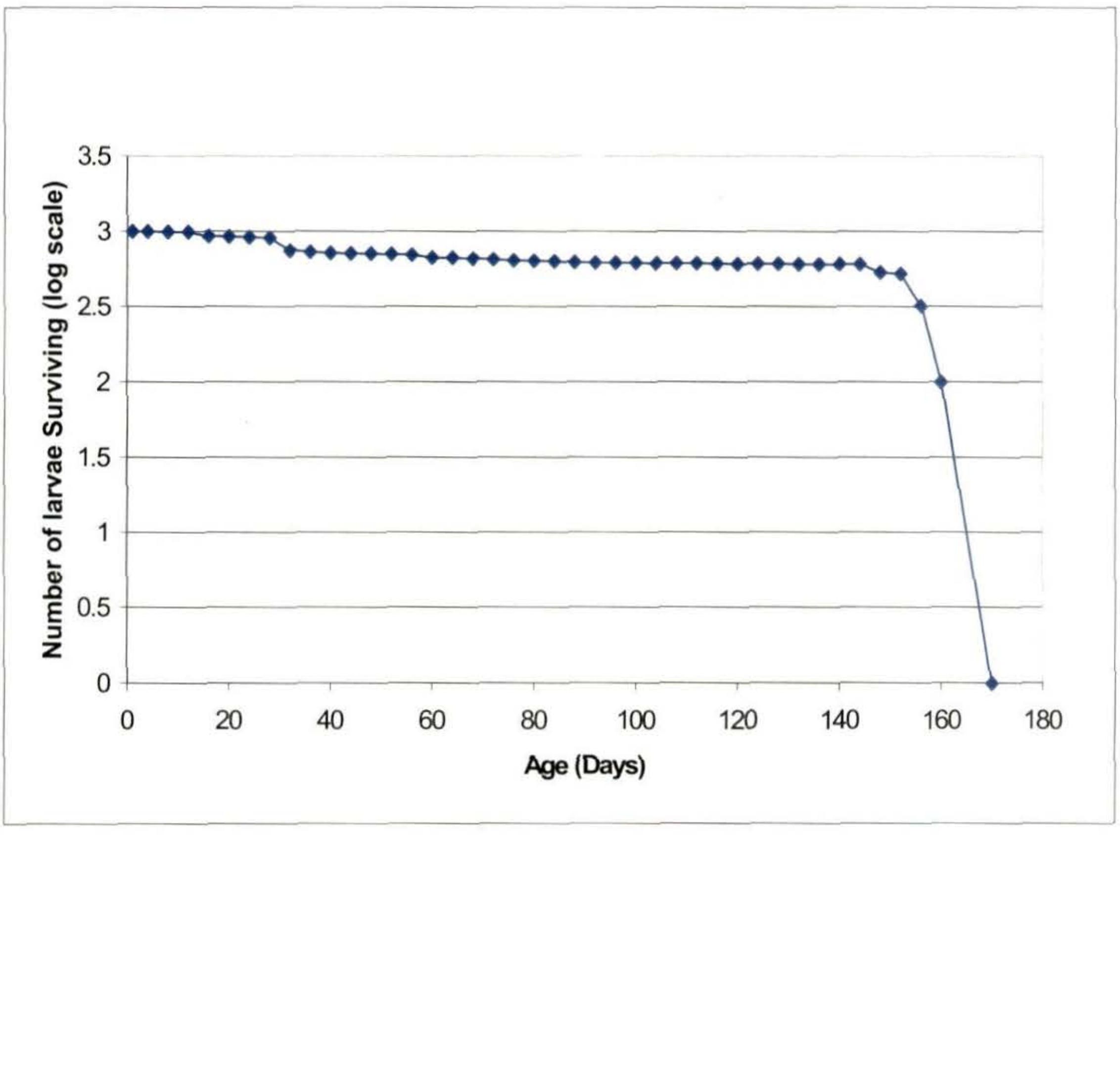
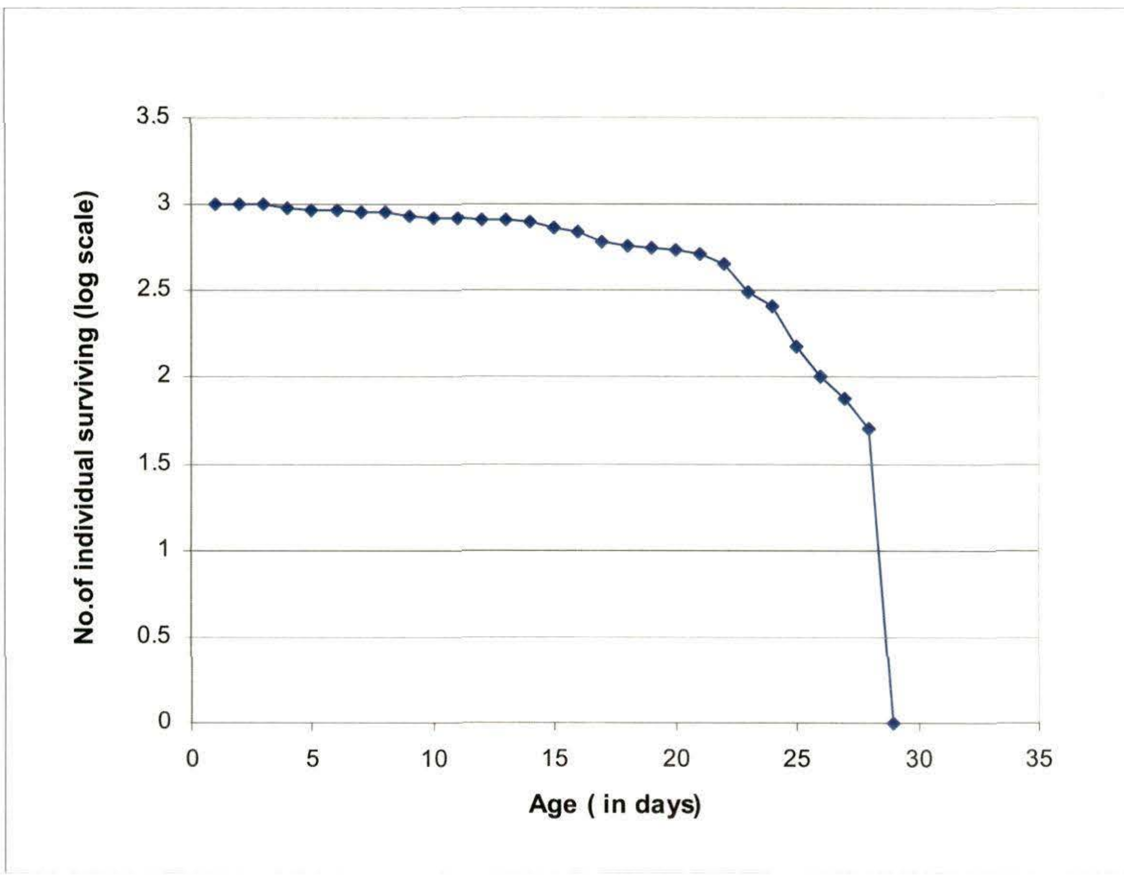


Table: 5b. Survivorship table of *C. chlorina*

X	l_x	d_x	L_X	T_X	e_x	$1000(q_x)$
0	1000.000	0	1000.000	18631.000	18.631	0.000
1	1000.000	2.000	999.000	17631.000	17.631	2.000
2	998.000	0.000	998.000	16632.000	16.665	0.000
3	998.000	48.000	974.000	15634.000	15.665	48.096
4	950.000	20.000	940.000	14660.000	15.432	21.053
5	930.000	12.000	924.000	13720.000	14.753	12.903
6	918.000	9.000	913.500	12796.000	13.939	9.804
7	909.000	11.000	903.500	11882.500	13.072	12.101
8	898.000	48.000	874.000	10979.000	12.226	53.452
9	850.000	10.000	845.000	10105.000	11.888	11.765
10	840.000	15.000	832.500	9260.000	11.024	17.857
11	825.000	6.000	822.000	8427.500	10.215	7.273
12	819.000	14.000	812.000	7605.500	9.286	17.094
13	805.000	20.000	795.000	6793.500	8.439	24.845
14	785.000	64.000	753.000	5998.500	7.641	81.529
15	721.000	32.000	705.000	5245.500	7.275	44.383
16	689.000	79.000	649.500	4540.500	6.590	114.659
17	610.000	35.000	592.500	3891.000	6.379	57.377
18	575.000	14.000	568.000	3298.500	5.737	24.348
19	561.000	11.000	555.500	2730.500	4.867	19.608
20	550.000	40.000	530.000	2175.000	3.955	72.727
21	510.000	60.000	480.000	1645.000	3.225	117.647
22	450.000	140.000	380.000	1165.000	2.589	311.111
23	310.000	55.000	282.500	785.000	2.532	177.419
24	255.000	105.000	202.500	502.500	1.971	411.765
25	150.000	50.000	125.000	300.000	2.000	333.333
26	100.000	25.000	87.500	175.000	1.750	250.000
27	75.000	25.000	62.500	87.500	1.167	333.333
28	50.000	50.000	25.000	25.000	0.500	1000.000

X= age in days, l_x = observed number of larvae surviving at start of X age interval, d_x =number dying during age interval x, L_X = number of individuals alive between ages x and x+1, T_X = individuals x time unit, e_x =expectation of life remaining for individuals of age x, q_x = mortality rate for an age interval.

Fig 6b. Survivorship curve of *C. chlorina*



6.7. Age distribution of *G. chrysolopha* and *C. chlorina*:

Using the information on morphometrics of the larvae, it was possible to analyze the age distribution of the natural population of *G. chrysolopha* and *C. chlorina* in different months of their occurrence. The changing age distribution of individuals, noted every fortnight for *G. chrysolopha,* showed different life stages in different months of their occurrence. It was found that the growing population had more number of younger age class i.e. III instar. As the time advanced and the population stabilized, more number of individuals from IV and V instars were found (Fig 7a). Therefore, it can be expected that the maximum injury (in terms of leaf consumed) done to the tree was by the larvae of the last two instars that dominated in the stable population for a longer time (Feb- April). Age distribution of *C. chlorina* in the present study, showed no clear period of dominance by a particular larval stage, although, in late June and early July, and again in the middle of August, IV instar larvae, were more frequent, showing partial dominance in the population. (Fig.7b).

6.8. Nutritional Indices of larvae of *G. chrysolopha*:

6.8.1. Feeding preference and quality of food consumed by *G. chrysolopha*:

The biochemical analysis of the quality of leaf consumed by *G. chrysolopha,* indicated that the larvae preferably consumed mature and senescent leaves having low percentage of basic nutrients (N: 1.500 ± 0.221, P: 0.055 ± 0.011, K: 0.753 ± 0.239 and C: 2.214 ± 0.389) with low water

Fig.7a. Age Distribution of larvae of *G. chrysolopha* in different months of their occurrence

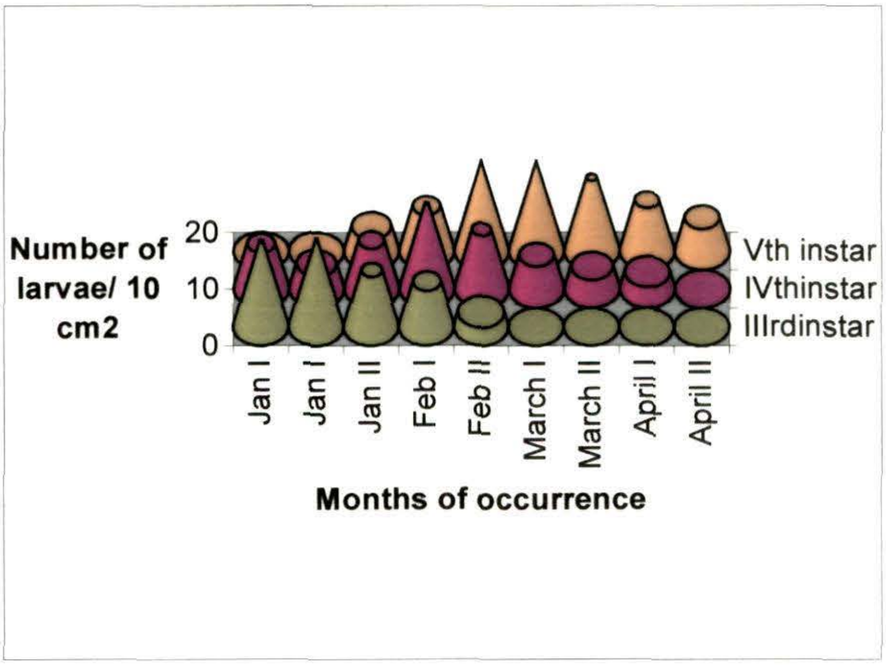
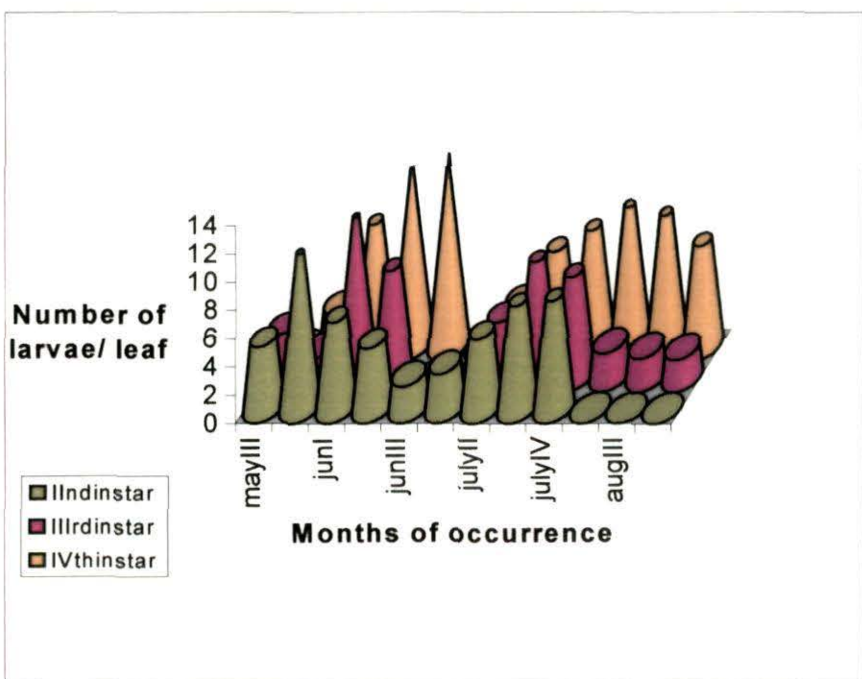


Fig. 7b. Age Distribution of larvae of *C. chlorina* in different months of their occurrence



content (60.5-65.2) % (Table: 6b). The analysis of P & K along with N & C was done with the objective to know its quantity present in the leaves and after the leaf is digested, the quantity present in the frass (faecal urine) as these are the essential components which determine the fertility of the soil (Weis and May, 1989).

6.8.2. Feeding behaviour:

In the field, the late instars larvae (3^{rd}, 4^{th}, 5^{th}) of *G. chrysolopha* showed nocturnal movement (migration) in procession. During the daytime, they rested in webs made by them at the base of the tree and at night they climbed tall trees reaching the canopy for food (foliage). When a larva encountered a leaf that was acceptable for feeding, it generally completely consumed it, starting from the margin leaving only the mid- rib. They fed only at night and returned to the base of the tree with the daybreak. It was observed that when the defoliation was severe, the tree took around two years to recover from the stress. In the laboratory, during the experimental period, most of the larvae were active feeders. In all the three stages, the larvae fed on host leaves from the margins. It was observed that larvae of *G. chrysolopha*, fed on senescent and mature leaves. Maximum feeding (18.845 gm/ larva /stadial period) was observed in the 5^{th} instar. Active feeding period for all the three instars, remained almost the same (Table 6c). Maximum feeding activity for all the three instar larvae was recorded at the middle of each stadial period and the larva stopped feeding before moulting (Fig 8).

Table: 6a. Comparison of basic nutrients (mean ± S.E) in leaves mainly consumed by *G. chrysolopha* and *C. chlorina*

	N (%)	P (%)	K (%)	Organic Carbon (%)
G. chrysolopha	$1.500^{a} \pm 0.221$	$0.055^{a} \pm 0.011$	$0.753^{a} \pm 0.239$	$2.214^{a} \pm 0.389$
C. chlorina	$2.877^{b} \pm 0.437$	$0.073^{b} \pm 0.010$	$1.205^{b} \pm 0.223$	$3.793^{b} \pm 0.308$

Values not followed by the same letter are significantly different ($p< .50$) using student's t test.

Table:6 b. Feeding preference of *G. chrysolopha* for shade tree leaves (*A. nepalensis*) of different maturity in relation to their moisture content

Leaf Type[1]	Mean leaf water content (%)	Mean leaf consumed(g) /day (mean ± S.E) / final instar larva
Type I	$75.151^{a} \pm 2.50$	Rejected
Type II	$72.855^{b} \pm 1.50$	$0.114^{a} \pm .051$
Type III	$70.206^{c} \pm 2.50$	$0.625^{b} \pm .199$
Type IV	$60.505^{d} \pm 3.50$	$0.615^{b} \pm .169$
CD (5%)	2.21	1.92

Means followed by same lower case letters are not significantly different at 5% level

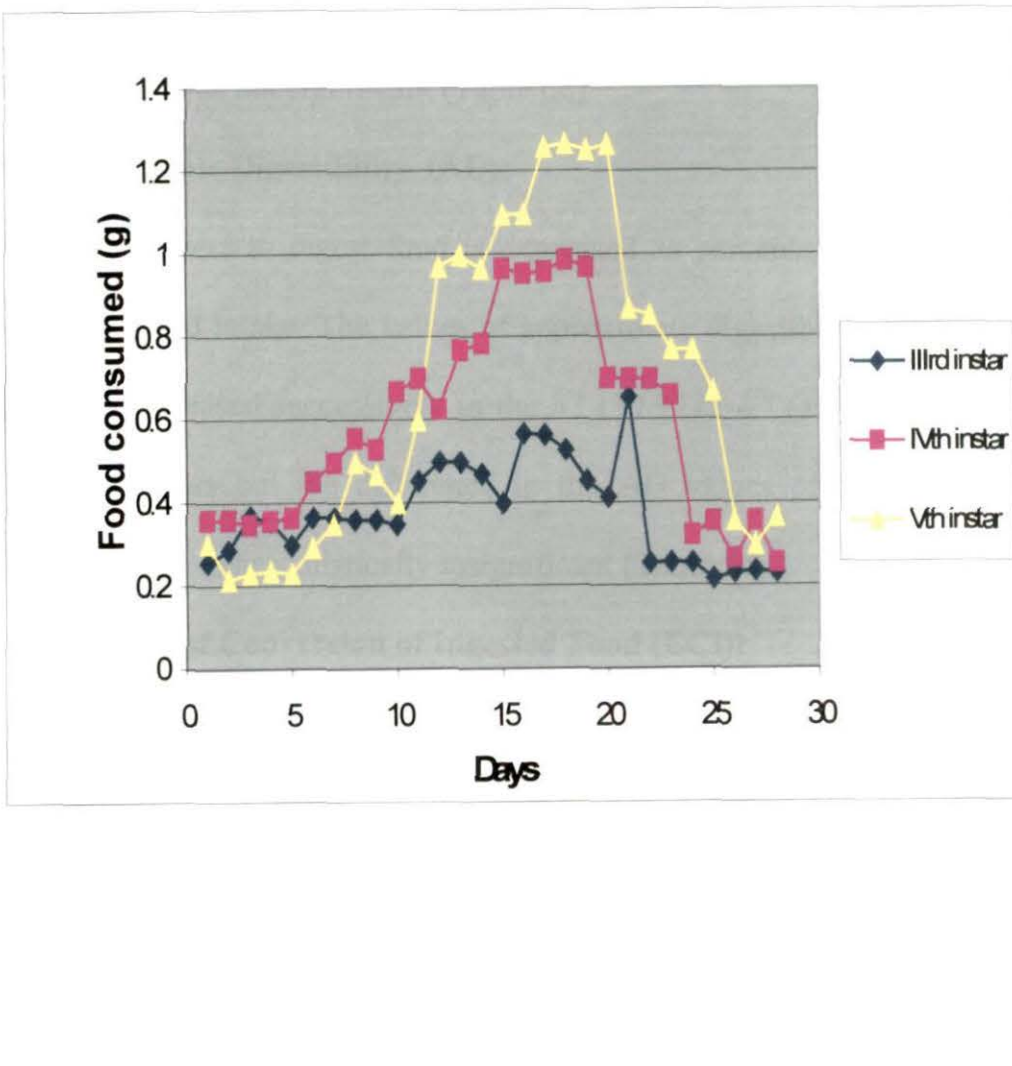
[1] Type I- Tender, Type II- Young, Type III- Mature, Type IV- Senescent

Table 6c. Food consumption (fresh weight), active feeding period and stadium (days) during development of *G. Chrysolopha* on leaves of *A. nepalensis* (Mean ± S.E)

Instar/ Stage	Stadial period	Active feeding period	Food Consumed (g)/ larva
III	$29.578^{a} \pm 3.454$	$25.050^{a} \pm 1.390$	$10.381^{a} \pm 1.024$
IV	$35.238^{b} \pm 3.624$	$25.500^{a} \pm 2.304$	$16.699^{b} \pm 1.262$
V	$34.750^{b} \pm 4.234$	$25.800^{a} \pm 2.409$	$18.845^{c} \pm 1.791$
CD (5%)	2.122	0.969	1.477

Means followed by same lower case letters are not significantly different at 5% level

Fig. 8. Food consumed by three larval stages of *G. chrysolopha* larvae during their stadial period



6.8.3. Consumption Index (CI): Consumption index (CI) indicates the rate of feeding in relation to the weight of the animal in a definite time interval. The data showed that CI value was highest in the 3rd instar and it progressively declined in the 4th and 5th instars. The CI value found in the 3rd instar (1.490) was significantly different from that in the 4th (1.187) and 5th (1.116) instars. However, the difference in the CI values for the 4th & 5th instars, was not significant (Table 6d).

6.8.4. Approximate Digestibility (AD):

Ability of an insect to digest food is expressed as percentage of food digested over food intake. The values of approximate digestibility for *G. chrysolopha,* increased successively in the 3rd (30.977), 4th (33.462) and 5th (34.983) instars but the difference in the AD values of the three instars, was found to be statistically insignificant (Table 6d).

6.8.5. Efficiency of Conversion of Ingested Food (ECI):

The efficiency, with which the ingested food is converted into body mass, is stated as percentage of weight gain over food intake. In this study, it was observed that ECI of the 3rd instar (4.123%) was higher than that of 4th (3.732%) and 5th (2.450%) instars. Significant difference was evident in the ECI values of the 4th and 5th instars, whereas no significant difference was noted between ECI values of the 3rd and the 4th instars (Table 6d).

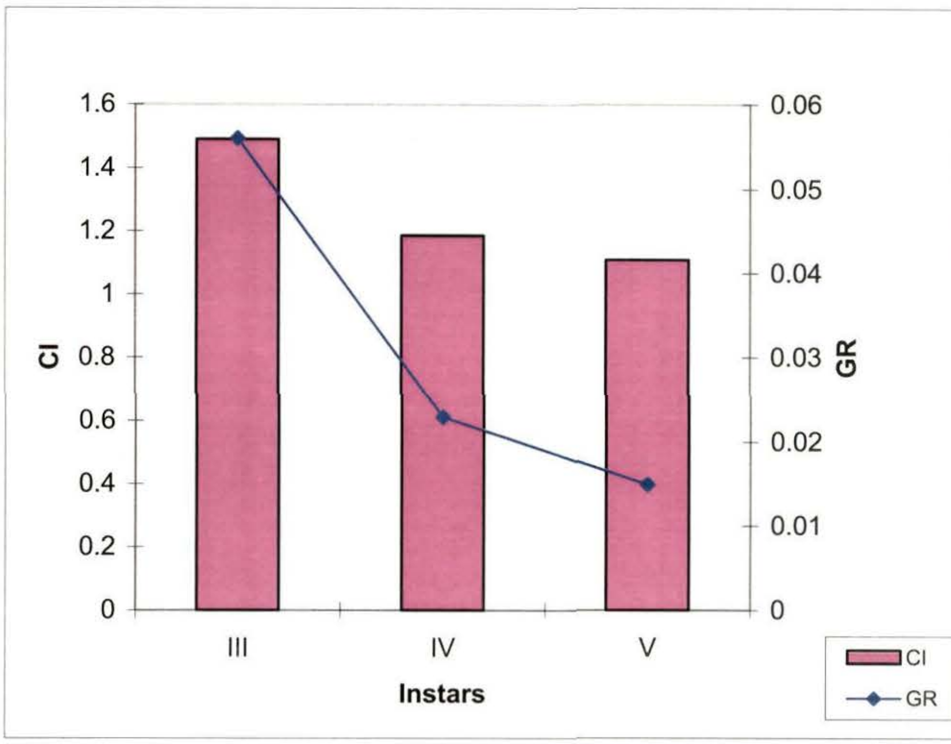
Table-6d. Nutritional & Growth indices of *G. chrysolopha* utilizing shade tree leaves *(A. nepalensis)* as food (Mean ± SE)

Instars	CI	GR	AD (%)	ECI (%)	ECD (%)
III	$1.490^{a} \pm 0.091$	$0.056^{a} \pm 0.002$	$30.977^{a} \pm 1.342$	$4.123^{a} \pm 0.393$	$7.564^{a} \pm 0.413$
IV	$1.187^{b} \pm 0.068$	$0.023^{b} \pm 0.023$	$33.462^{a} \pm 2.451$	$3.732^{a} \pm 0.211$	$5.085^{b} \pm 0.319$
V	$1.116^{b} \pm 0.080$	$0.015^{c} \pm 0.001$	$34.983^{a} \pm 2.048$	$2.450^{b} \pm 0.191$	$3.612^{c} \pm 0.220$
CD (5%)	0.258	0.000	5.706	0.773	0.997

Means followed by same lower case letters are not significant at 5% level

CI = Consumption Index
GR = Growth Rate
AD = Approximate Digestibility
ECI = Efficiency of conversion of Ingested food
ECD= Efficiency of conversion of Digested food

Fig. 9a. Relation between GR and CI of *G. chrysolopha*



GR =Growth rate

CI = Consumption Index

6.8.6. Efficiency of Conversion of Digested Food (ECD):

The efficiency with which the digested food is converted into body mass, is presented as the percentage of weight gain over food digested. Highest value for it was observed in the 3^{rd} (7.564%) followed by 4^{th} (5.085%) and 5^{th} (3.612%) instars, all with a significant difference. (Table 6d).

6.8.7. Growth Rate (GR):

The growth rate indicates the rate at which digested food is available to the animal and, ultimately, the increase in per gram body weight per day. In the present study, the result of growth rate for *G. chrysolopha* reared on *A. nepalensis,* showed the highest value in the 3^{rd} instar (.056) followed by 4^{th} (.023) and 5^{th}(.015) instars (Table 6d). GR in all the three instars was found significantly different from each other. A positive relationship was observed between consumption index and growth rate (Fig 9a).

6.9. Nutritional Indices of larvae of *C. chlorina*:

6.9.1. Feeding preference and the quality of food consumed by *C. chlorina*:

The biochemical analysis of the quality of leaf consumed by *C. chlorina,* revealed that the larvae preferably consumed new leaves, rich in nutrient percentages (N: 2.877 ± 0.437, P: 0.073 ± 0.010, K: 1.205 ± 0.223 and C: 3.793 ± 0.308) (Table 6a) with high water content (75.15 ± 2.50%) (Table 7a).

Table: 7a.Feeding preference of *C. chlorina* larvae for shade tree leaves (*A. nepalensis*) of different maturity in relation to their moisture content

Leaf Type[2]	Mean leaf water content (%)	Mean leaf consumed/day (g ± S.E) / final instar larva
Type I	$75.457^{a} \pm 2.50$	$0.1045^{a} \pm 0.095$
Type II	$72.650^{b} \pm 1.22$	$0.0999^{b} \pm 0.071$
Type III	$70.055^{c} \pm 1.75$	$0.0499^{c} \pm 0.001$
Type IV	$65.451^{d} \pm 1.42$	Rejected
CD (5%)	2.552	0.000

Means followed by same lower case letters are not significant at 5% level

Table: 7b. Food consumption (fresh weight), active feeding period and stadium (days) during development of *C. chlorina* larvae on leaves of *A. nepalensis* (Mean ± S.E)

Instar/ Stage	Stadial period	Active feeding period	Food Consumed (g)/ larva/ day
II	$3.5^{a} \pm 0.051$	$3.5^{a} \pm 0.051$	$0.309^{a} \pm 0.075$
III	$3.5^{a} \pm 0.047$	$3.5^{a} \pm 0.047$	$0.451^{b} \pm 0.095$
IV	$4.5^{b} \pm 0.1950$	$4.5^{b} \pm 0.507$	$0.514^{c} \pm 0.102$
CD (5%)	0.109	0.110	0.000

Means followed by same lower case letters are not significant at 5% level

[2] Type I- Tender, Type II- Young, Typè III- Mature, Type IV- Senescent

6.9.2. Feeding behaviour:

First instar larvae showed gregarious/aggregate feeding habit. Larvae of the 2^{nd}, 3^{rd} and 4^{th} instars, skeletonized whole leaf leaving only the mid- rib. (Plate 8b). Generally, the feeding was done during daytime. Maximum food (0.514 g/larvae) was consumed by the 4^{th} instar of *C. chlorina.* All the three instars fed throughout the stadial period (Table 7b).

The adult behavior consisted of short feeding periods followed by extensive wandering. Nutritional parameters of the 1^{st} instar larvae could not be studied because they nibbled very little amount of green matter of the leaves.

6.9.3. Consumption Index (CI):

The data obtained in the present study showed that the larvae of *C. chlorina* on *A. nepalensis* had short development time with significantly higher Consumption Index. The CI value was highest (0.935) in the 4^{th} instar as compared to the values of the 3^{rd} and 2^{nd} instars. The values, however, were not significantly different (Table 7c).

6.9.4. Approximate Digestibility (AD):

Highest AD value was recorded in the 2^{nd} instar (72.449%) that gradually declined in the subsequent instars. However, a significant difference was observed among the 3^{rd} and 4^{th} instars.

An overall high AD was observed in all the instars of *C. chlorina* on *A. nepalensis* (Table 7c).

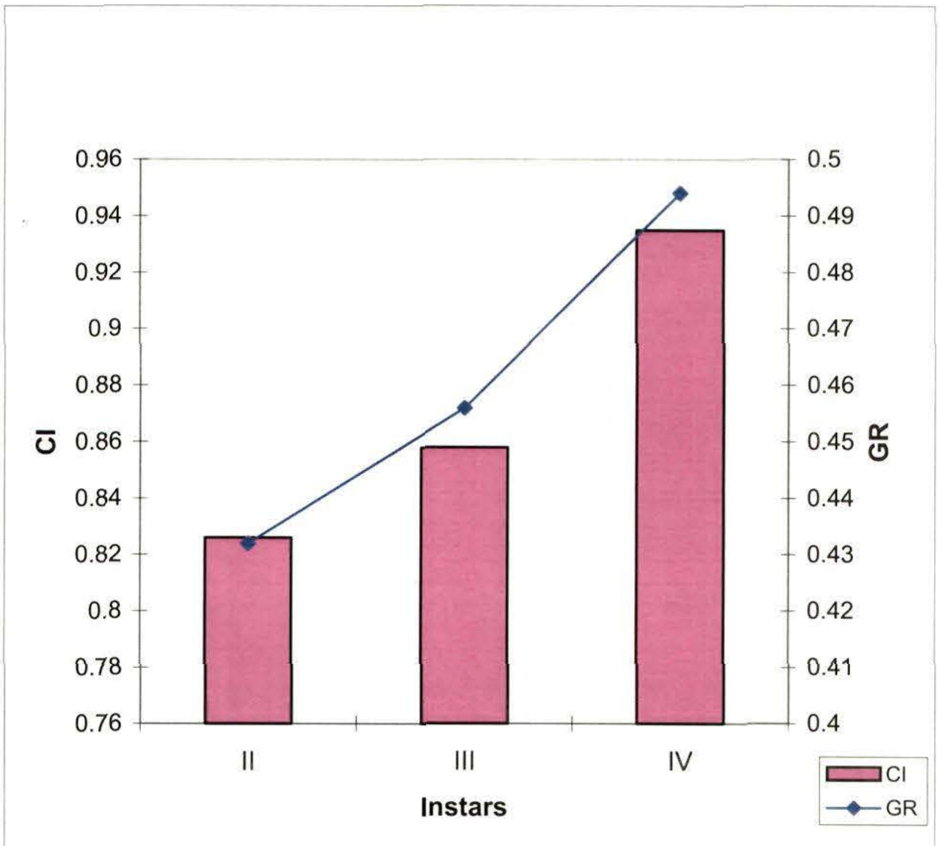
Table-7c. Nutritional & Growth Parameters in relation to food *(A. nepalensis)* utilization by *C. chlorina* (Mean ± SE)

Instars	CI	GR	AD (%)	ECI (%)	ECD (%)
II	$0.826^{a} \pm .015$	$0.432^{a} \pm .011$	$72.449^{a} \pm 2.046$	$18.969^{a} \pm 0.135$	$38.961^{a} \pm 0.325$
III	$0.858^{a} \pm .028$	$0.456^{a} \pm .021$	$70.318^{a} \pm 2.141$	$17.985^{b} \pm 0.125$	$38.554^{a} \pm 0.342$
IV	$0.935^{a} \pm .041$	$0.494^{a} \pm .065$	$61.445^{b} \pm 2.182$	$17.978^{b} \pm 0.119$	$36.998^{a} \pm 0.314$
CD (5%)	0.244	0.157	4.407	0.631	2.853

Means followed by same lower case letters are not significant at 5% level

CI = Consumption Index
GR = Growth Rate
AD = Approximate Digestibility
ECI = Efficiency of conversion of Ingested food
ECD= Efficiency of conversion of Digested food

Fig 9b. Relation between GR and CI of *C. chlorina* on *A. nepalensis*



GR =Growth rate

CI = Consumption Index

6.9.5. Efficiency of Conversion of Ingested Food (ECI):

ECI of *C. chlorina* decreased from the 2^{nd} to the 4^{th} instar. Significant difference was observed in the ECI values of the 2nd and 3^{rd} instar larvae (Table 7c).

6.9.6. Efficiency of Conversion of Digested Food (ECD):

ECD value was found to decrease with the advancing stages. ECD value was highest (38.961%) in the 2^{nd} instar but was not significantly different from that of the 3^{rd} and 4^{th} instars.

6.9.7. Growth Rate (GR):

Highest growth rate (0.494) was recorded in the 4^{th} instar larvae (Table 7c). No significant difference in GR was observed between the instars. A positive relationship was observed between consumption index and growth rate of the larvae (Fig 9b).

6.10. Evaluation of ecological role of the major folivores:

6.10.1. Positive role:

6.10.1.1. Analysis of faecal urine of *G. chrysolopha* and *C. chlorina* (Table 8):

Faecal- urine produced by the folivores usually fell to the soil below the shade tree. Soil mixed with faecal-urine was tested at monthly interval for three consecutive months for both the folivores, *G. chrysolopha* and *C. chlorina.*

It was observed that faecal-urine of both the larvae had very little percentage of nitrogen, phosphorous, potassium and organic carbon that

Table: 8. Comparison of basic fertility component present in faecal urine produced by *G. chrysolopha* and *C. chlorina*

	N (%)	P (%)	K (%)	Organic Carbon (%)
G. chrysolopha	0.00225	traces	.000240	0.0856
C. chlorina	0.0102	traces	.000754	1.0526

No significant difference in the values

Table: 9a. Variation in composition with time of the soil mixed up with the faecal urine of *G. chrysolopha*

Soil Samples	N (%)	P (%)	K (%)	Organic Carbon (%)
Control	0.256± 0.053	traces	traces	0.276± 0.0121
Month I	0.256± 0.053	traces	traces	0.276± 0.0121
Month II	0.295± 0.064	traces	traces	0.296± 0.0104
Month III	0.295± 0.047	traces	traces	0.295± 0.0155

No significant difference in the values in three consecutive months

Table: 9b. Variation in composition with time of the soil mixed up with the faecal urine of *C. chlorina*

Soil Samples	N (%)	P (%)	K (%)	Organic Carbon (%)
Control	0.292± 0.022	traces	traces	0.295± 0.0174
Month I	0.292± 0.022	traces	traces	0.295± 0.0174
Month II	0.301± 0.045	traces	traces	0.354± 0.0158
Month III	0.299 ± 0.095	traces	traces	0.355± 0.0104

No significant difference in the values in three consecutive months could add to soil fertility. Results of this study indicated that the composition of faecal urine being very low in the basic fertility components, were not contributing much as manure.

6.10.1.2. Analysis of soil mixed with faecal urine:

Assessment of the changes in soil fertility with time was done through soil analysis. The result showed very little changes in the fertility components (N.P, K and organic C) of the soil during the three months of observation. So, the basic fertility property of the soil remained unchanged (Table 9a and 9b). It can be inferred that faecal -urine of both the pests that dropped to the soil at the foot of the shade tree (*A. nepalensis*), did not contribute any organic fertility to the top soil, despite decomposition within the span of 3 months.

6.10.2. Negative role:

6.10.2.1. Estimation of the extent of injury done to the leaves by the major folivores:

The observations made to assess the extent of injury done to the leaves by the larvae of *G. chrysolopha* and *C. chlorina* showed that in all the three years, percentage of injury done to the leaf, by and large, remained similar. In general, the larvae of *G. chrysolopha* caused more injury to *A. nepalensis* than the larvae of *C. chlorina,* by consuming greater amount of leaves in terms of leaf area (Table 10a).

Table: 10a. Leaf area consumed (in %) by final instar larvae of *G. chrysolopha* and *C. chlorina* (n=10)

Years	Leaf area consumed (Mean ± S.E) /larva/day
G. chrysolopha	16.565[a] ± 0.185
C. chlorina	7.987[b] ± 0.095 *

* significant at $p < .05$ (student's t test)

Table: 10b. Efficiency of Growth and Food Utilization by *C. chlorina* on *Alnus nepalensis* (A) and *Amomum subulatum* (B)

Instars	CI	GR	AD (%)	ECI (%)	ECD (%)
			A		
III	0.826 ± .015	0.432 ± 0.011	72.449 ± 2.046	18.969 ± 0.135	38.961± 0.325
IV	0.858 ± .028	0.456 ± 0.021	70.318 ± 2.141	17.985 ± 0.125	38.554 ± 0.342
V	0.935 ± .041	0.494 ± 0.065	61.445 ± 2.182	17.978 ± 0.119	36.998 ± 0.314
			B		
III	0.795 ± .057	0.404 ± 0.002	70.535 ± 2.534	18.013 ± 0.247	38.564 ± 0.227
IV	0.729 ± .084	0.394 ± 0.001	65.235 ± 3.228	17.32 ± 0.241	35.355 ± 0.334
V	0.726 ± .098	0.384 ± 0.023	63.654 ± 2.156	16.245± 0.223	33.162 ± 0.292

6.10.2.2. Estimation of injury potential of *C. chlorina* utilizing cardamom leaves as alternate food:

As mentioned earlier, out of the two major folivores (*G. chrysolopha* and *C. chlorina*), *C. chlorina* inflicted injuries to the leaves of cardamom plants also. Therefore, to assess the direct injury potential of *C. chlorina,* nutrition indices of the pest were calculated when it fed on cardamom leaves. The consumption and conversion values indicated that this pest could utilize both its host leaves with almost equal efficiency (Table 10b). The result obtained here suggested that *C. chlorina*, due to its polyphagous habit, could cause substantial injury to the cardamom leaves also. Such direct crop injury besides the injury caused to the shade tree leaves, establishes the negative role of *C. chlorina* in the cardamom agroforestry system.