5: OBSERVATION AND RESULTS

I FAUNISTIC STUDY

i. Richness of fern species and associated entomofauna from Darjeeling plain

Terrestrial ferns were found to have a fair distribution along Darjeeling plain. Eighteen species were so far recorded from diverse habitat. Ferns tend to grow mostly as undergrowth of forest in shady areas, around pastures, flanking tea gardens and by the sides of water ways and road. Some of the species were commonly seen and constituted the major bulk of the apparent sporophytes. The common sight of the genera Christella, Diplazium , Microlepia, Lindsea and Dicranopteris as discrete populations and even at times in mixed forms in patches, establish their richness in Darjeeling plains. The list of fern species (Table I) also include a number of non-apparent species having a limited distribution. These non-apparent species have been excluded in the present study of fern entomofauna. The fern species listed might have one or more associated insects species, however, the major observation had been done on five common ferns having apparently a wider distribution in this region.

ii. Distribution and frequency of occurrence of five common fern species

An ecological investigation to find out the frequency of occurrence of the five most apparent species along the Darjeeling plain showed some pattern of distribution. A general observation in the plain of Darjeeling indicated that five of the terrestrial ferns were more apparent and had an extensive distribution. Two of the five species i.e. *Diplazium esculentum* and *Christella crinipes* showed a higher frequency of distribution (Table II).

iii. Annotated account of insects associated with some apparent fern species

a. Association of insect and fern species :-

Insects were found to use fern species as true hosts, as alternate hosts, as alternative hosts, as roost and shelter. An elaborate list of the insects found associated with the fern sporophytes has been provided (Table III). Only mention of those host plants has been made where a certain association has been observed. The name of the host plant could not be provided for those insects collected by sweeping from mixed fern vegetation.

A list giving famillial distribution and taxonomic analysis at order, family, genera and species level is also provided (Table IV) indicating that the species of Coleoptera and Hemiptera constitute the largest groups followed by Lepidoptera, Orthoptera, Thysanoptera and Hymenoptera.

b. Species commonly involved in insect-fern-crop interaction :-

An orthopteran species, Atractomorpha crenulata, two lepidopteran species Spilarctia obliqua and Spilarctia casigneta, two coleopteran species Astycus lateralis and Mylloceros discolour, two hemipteran species Agonoscelis nubila and Eusarcocoris ventralis, and one thysanopteran species Heliothrips haemorrhoidalis have been noted to be common to crops and economic plants (Table V)

c. Species acting as predators and parasites

It had been observed that a number of predators and parasites/ parasitoids used the fern entomofauna as their prey / host. The same entomophagous insects have also been found to have potentiality to attack crop pests.

Apanteles sp. is a well known larval parasitoid which bred on the larvae of Spilarctia obliqua (Fig. 10) and Psara ustulalis. The eggs of S. obliqua were found to be parasitized by chalcids. A species of tachinid fly was recorded to be a larval pupal parasite of S. casigneta (Fig.11). The fern aphid Tinocallis himalayensis were also found to be parasitized by a hymenopteran. The omnivorous predator Eusarcocoris ventralis had been found to feed on the soft bodied larvae of the saw fly.

d. Seasonal occurrence of fern associated insects

In the winter months (November to March) most of the fern associated insects were from the order Coleoptera and Hemiptera. Besides this, in early winter, some micro-lepidopteran species and a species of hymenopteran occurred. Spring starts in April and with the sprouting of fresh fronds that mature along with the onset of monsoon in the month of June, a number of lepidopteran, coleopteran, orthopteran and a homopteran and parasitic hymenopteran species become prevalent. During rainy season, which continues till October, an active occurrence of most of the fern chewers including the sawfly could be recorded (Table VI).

Fig.12a. Intact frond of host D. esculentum. of S. obliqua . (before feeding/ preference test)

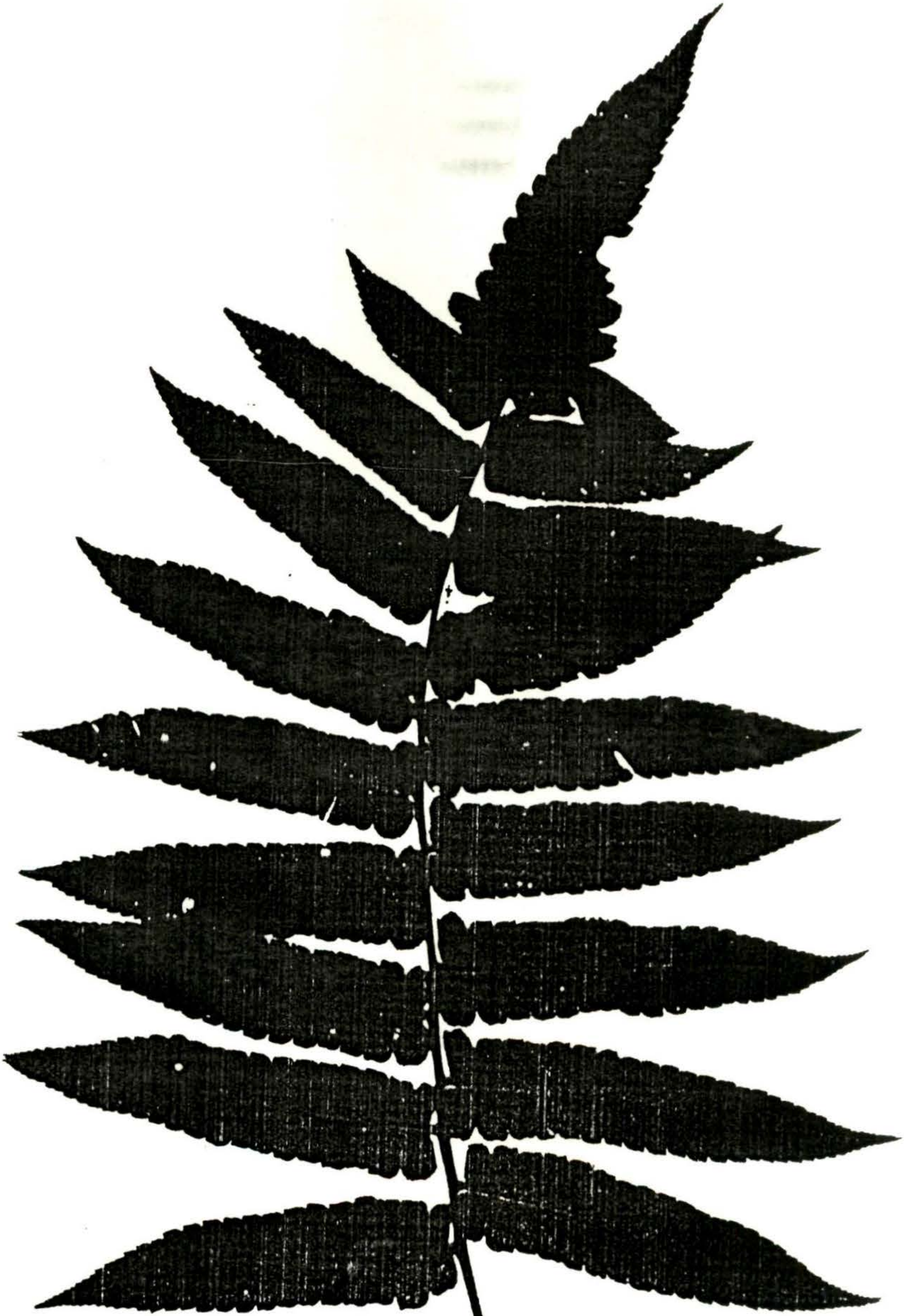


Fig.12a.

Fig.12b. Remaining part of *D. esculentum* after feeding by late instar larvae of *S. obliqua*.

Fig.12b.

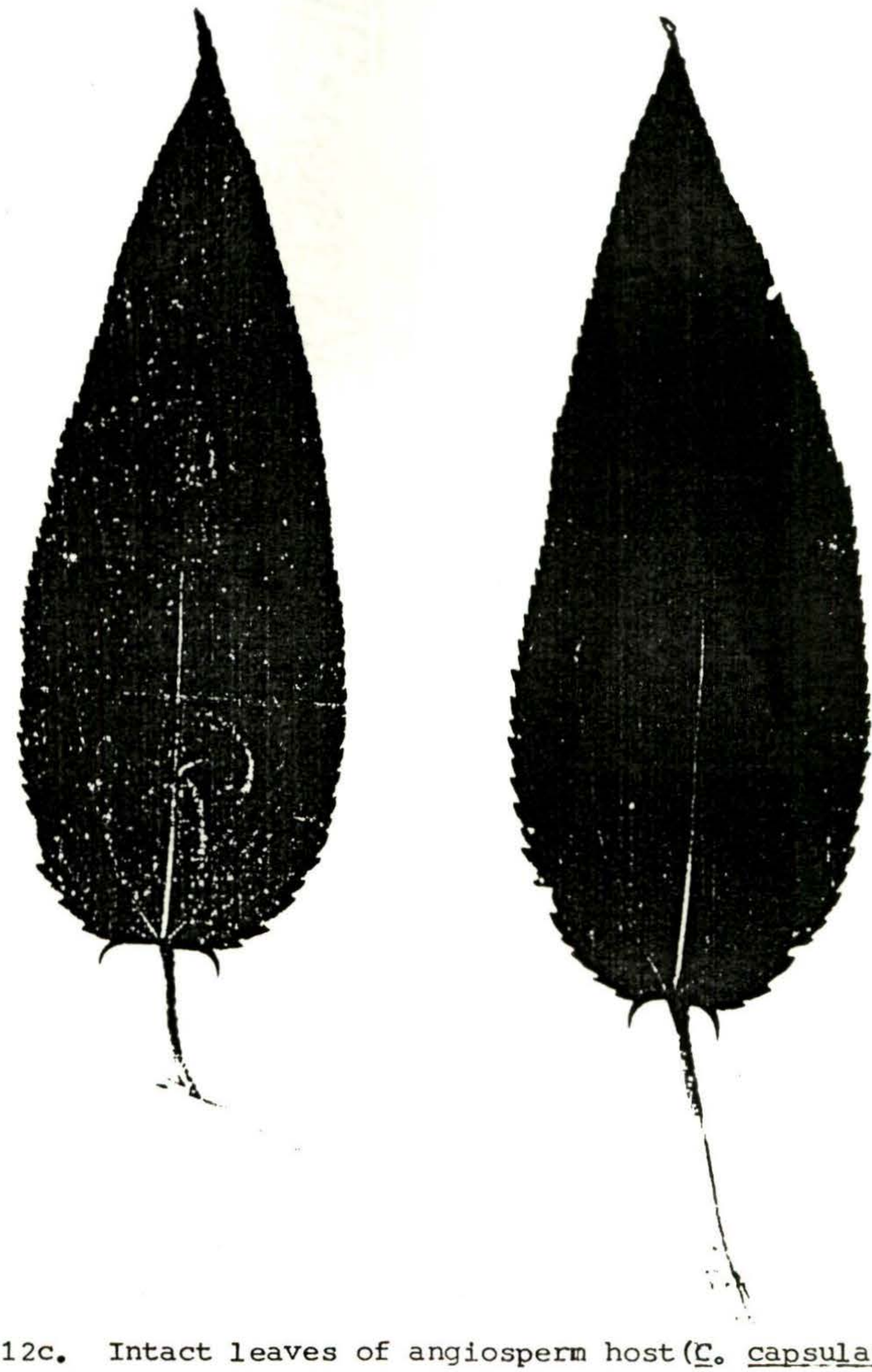


Fig.12c. Intact leaves of angiosperm host (C. capsularis) of S. obliqua.

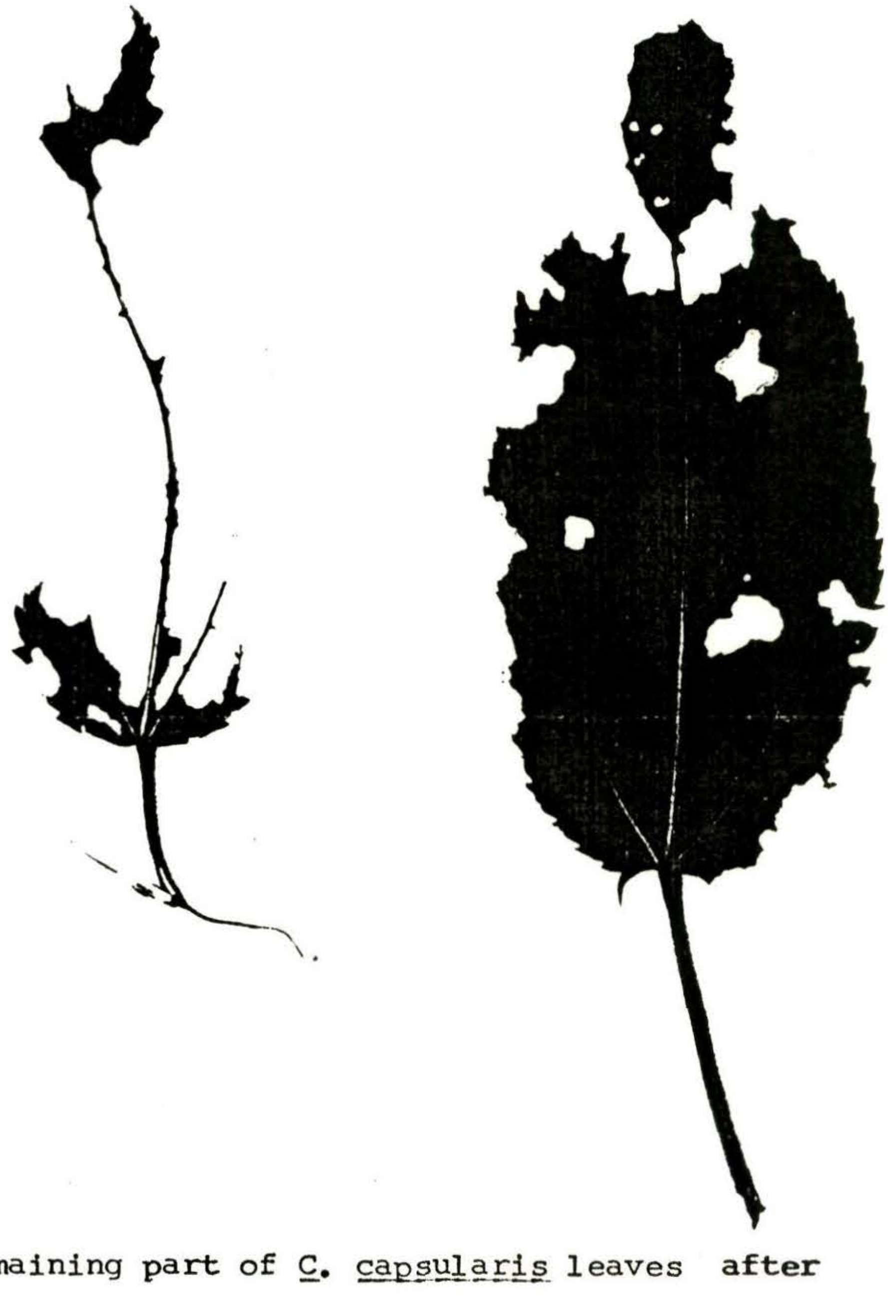


Fig.12d. Remaining part of C. capsularis leaves after feeding by late instar larvae of S. obliqua.

Table VII: Host plant preference by *Spilarctia obliqua* (a,b) calculated in percentage of leaf area consumed / insect/ hour.

a.

	F E R N S				
Stage	*D. esculentum*	*C. crinipes*	*M. speluncae*	*L. ensifolia*	*D. linearis*
Early larva	0.07	-	-	-	-
Advanced larva	1.29	-	-	-	-

b.

STAGE	F E R N - A N G I O S P E R M	
	D. esculentum	*C. capsularis*
Early larva	-	0.06
Advanced larva	1.41	1.56

Fig.13. Eggs of *Spilarctia obliqua* on leaf of *Corchorus capsularis* .

Fig.14a. Early instar larvae of *S. obliqua* on *Diplazium esculentum*.

Fig.14b. Early instar larvae of S. obliqua on *Corchorus capsularis*.

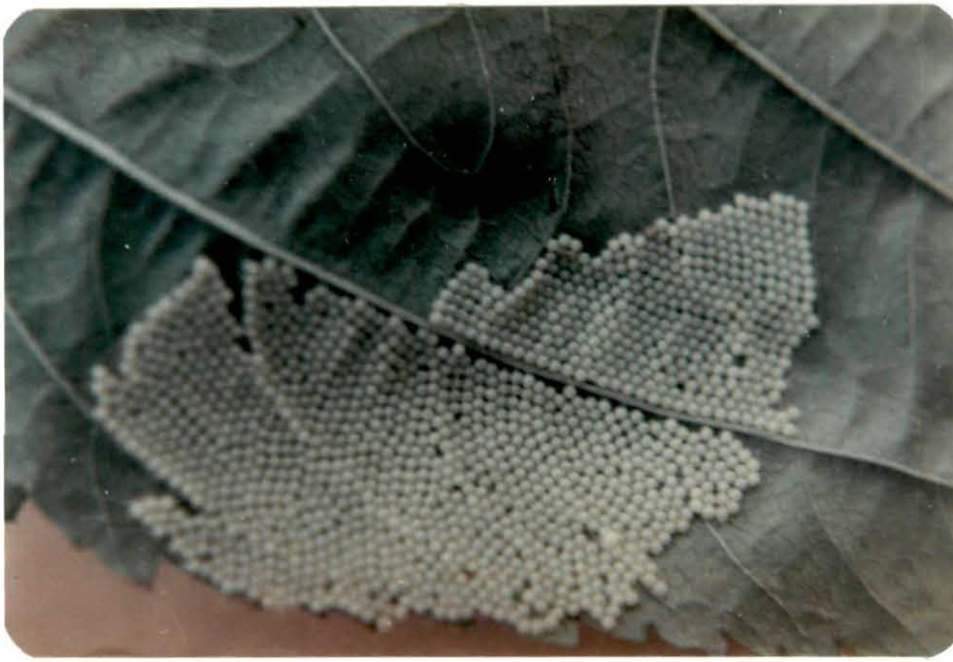


Fig.13

Fig.14a.

Fig.14b.

Fig.14c. Late instar larvae of *S. obliqua* on *D. esculentum*.

Fig.15. Pupae of *S. obliqua* on *D. esculentum*.

Fig.14c

Fig.15.

Fig.16a. Female of *S. obliqua* on *C. capsularis*.

Fig.16b. Male of *S. obliqua* on *C. capsularis*.

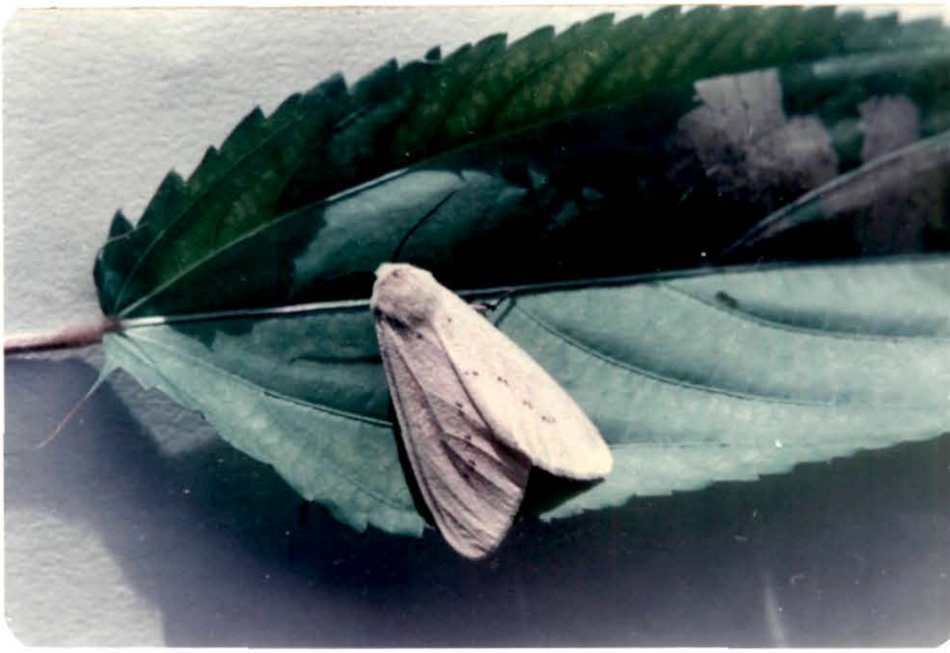


Fig.16a.

Fig.16b.

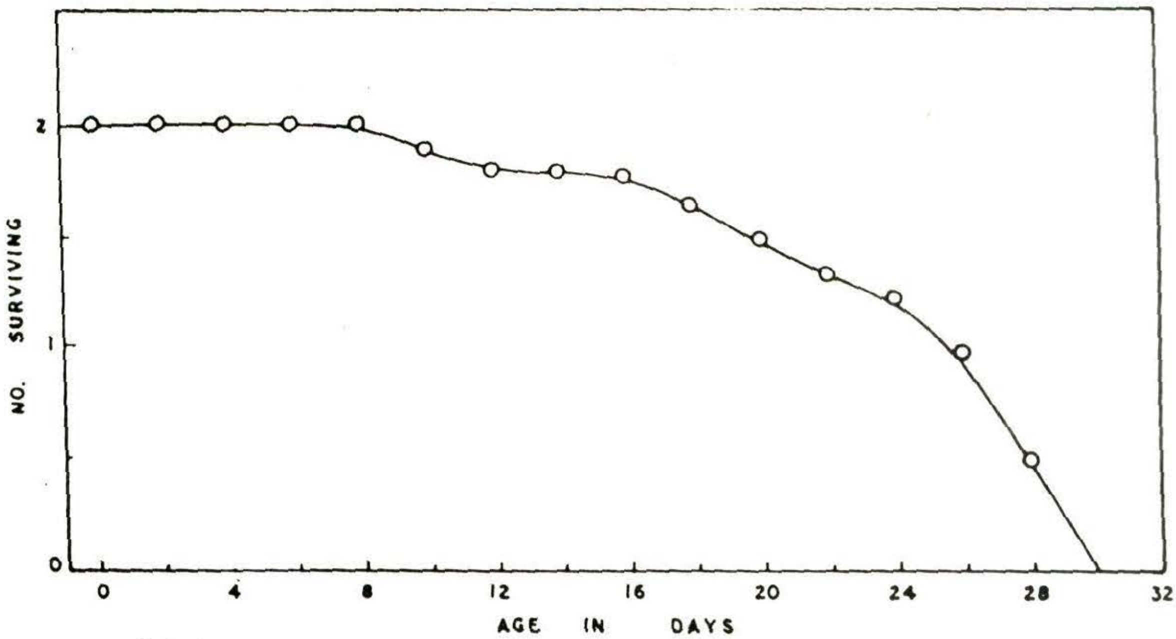


FIG. 17 a.

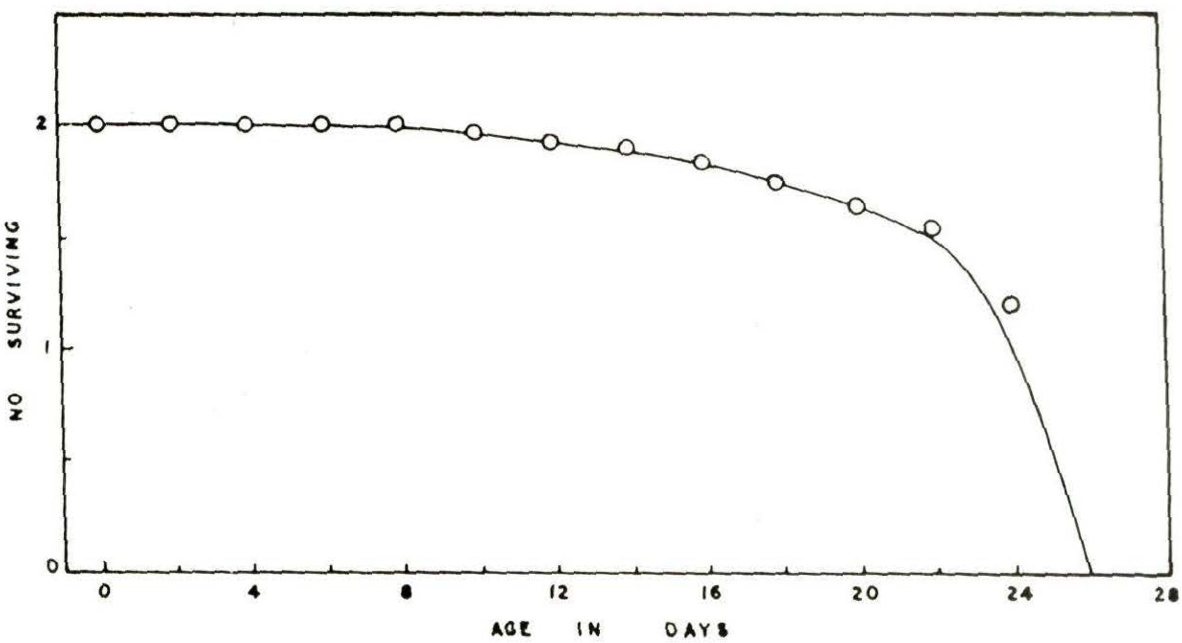
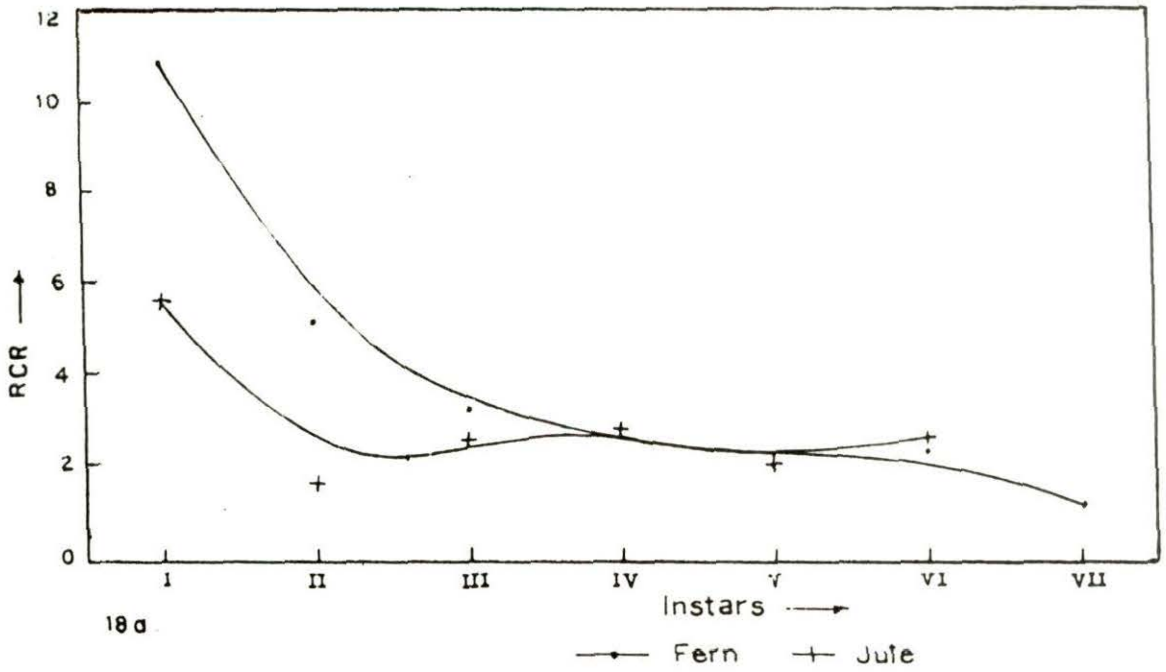


FIG. 17 b.

Fig. 17a. Survivorship curve of S. obliqua on D. esculentum.

Fig. 17b. Survivorship curve of S. obliqua on C. capsularis.



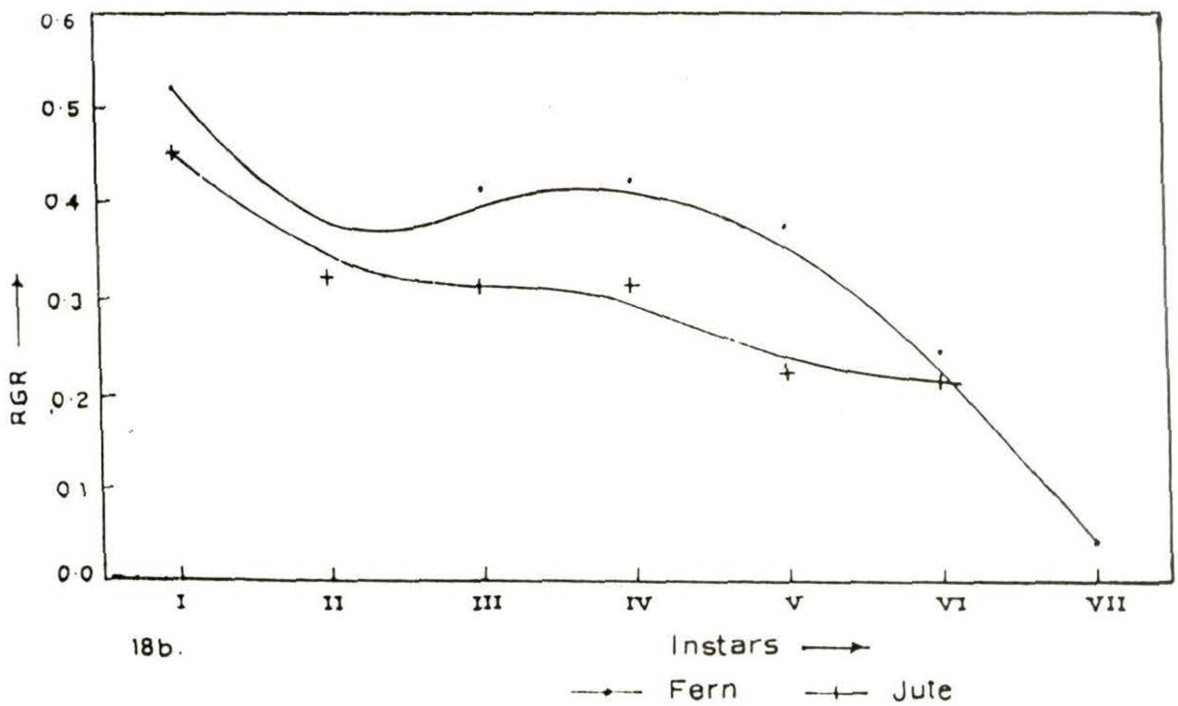
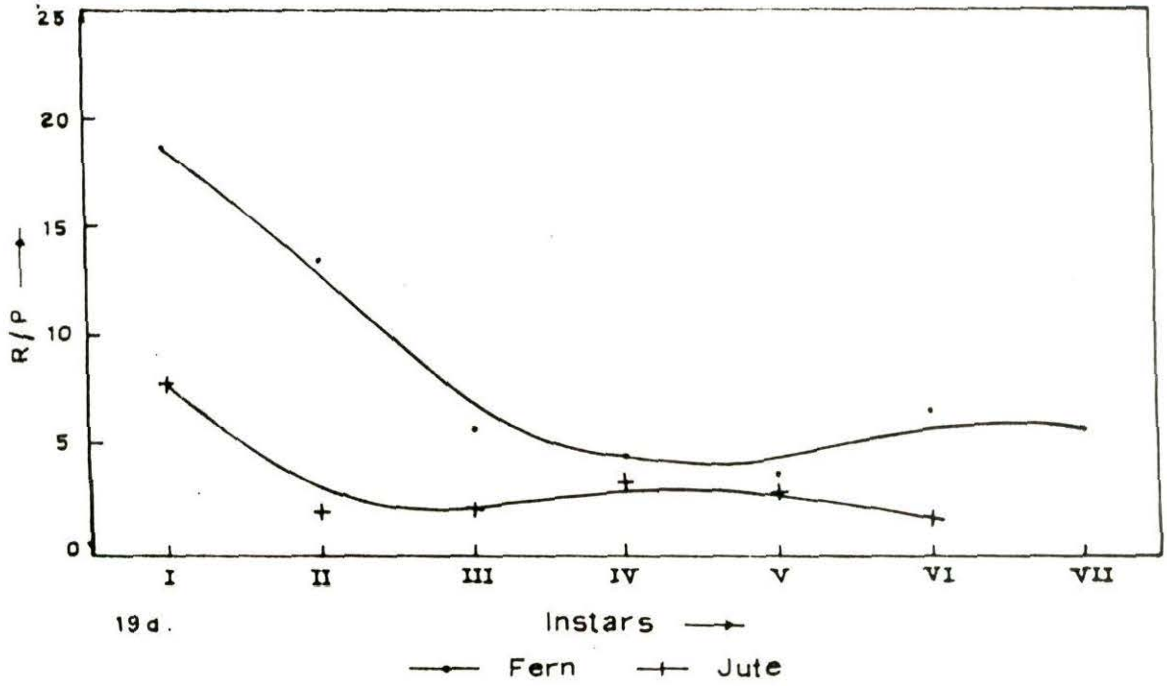


Fig.18a. Relative consumption rate of different larval stages of S. obliqua on D. esculentum and C. capsularis.

Fig.18b. Relative growth rate of different larval stages of S. obliqua on D. esculentum and C. capsularis.



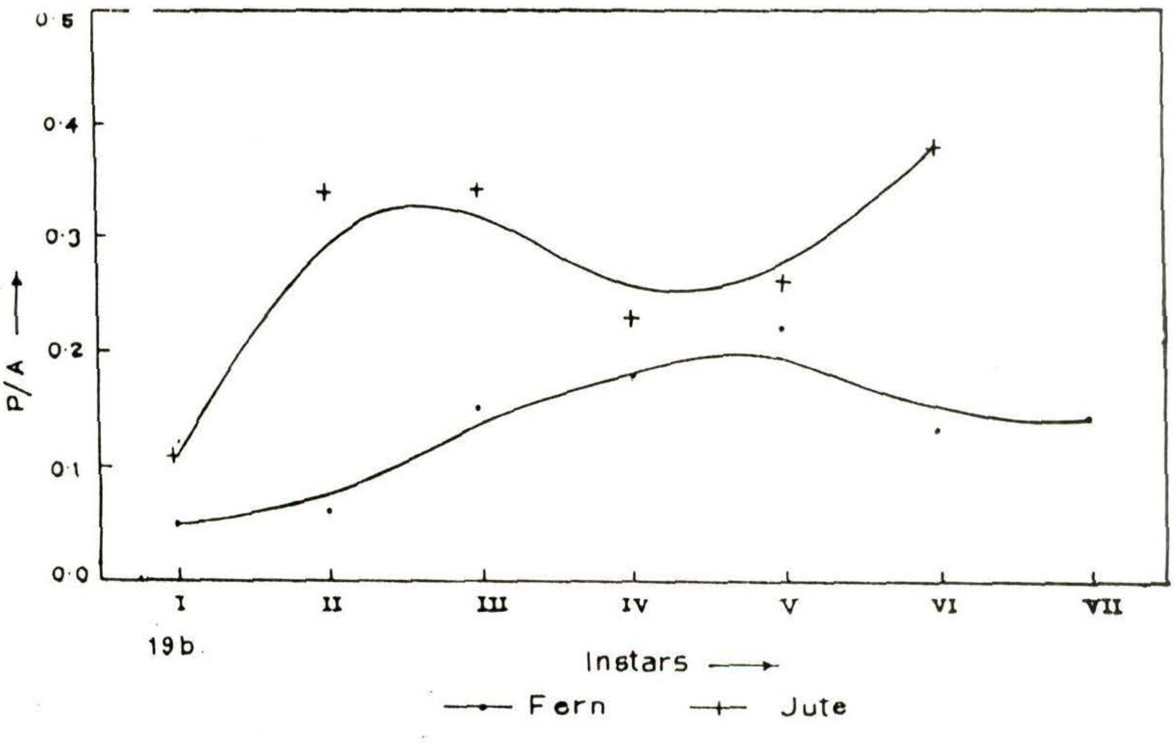


Fig.19a. Comparison of maintenance cost (R/p) of different larval stages of S. obliqua on D. esculentum and C. capsularis.

Fig.19b. Comparison of production index (P/A) of different stages of S. obliqua on D. esculentum and C. capsularis.

Table VIII a. Performance of *S. obliqua* on fern (*D. esculentum*) and angiosperm (*C. capsularis*) hosts (Mean ± SD)

Host Plant	Pupal dry wt (mg)		Adult emergence (%)	Adult dry wt. (mg)		Longevity (days)		Fecundity
	Male	Female		Male	Female	Male	Female	
Diplazium esculentum	27.54 ±1.26	59.97 ±1.01	27.08 ±1.16	25.95 ±1.55	56.17 ±1.05	6.14 ±0.88	3.94 ± 1.02	134.60 ±31.52
Corchorus capsularis	47.98 ±1.23	93.68 ±1.16	81.33 ±0.92	37.98 ±1.18	85.36 ±1.25	7.88 ±0.67	6.36 ±0.88	918.25 ±38.96

Table VIII b. Duration (days) and survival (%) of different stages of *S. obliqua* on fern (*D. esculentum* and angiosperm host (*C. capsularis*) (Mean ± SD)

Stage	P-Period S-Survival	HOST PLANT	
		D. esculentum	*C. capsularis*
Larval	P	1 - 24	1 - 21
	S	17.46 ± 1.39	35.38 ± 0.90
Prepupal	P	25 - 26	22 - 23
	S	16.34 ± 1.24	32.84 ± 1.57
Pupal	P	27 - 36	24 - 33
	S	10.40 ± 1.61	33.36 ± 1.71
Egg	P	Eggs laid but	0 - 5
	S	unhatched	98.89 ± 0.22

Table IX a : Survivorship table for the larvae of

<u>S. obliqua</u> on <u>D. esculentum</u>

x	n_x	l_x	L_x	T_x	e_x	q_x
0	100	1.000	100	830.0	8.30	0
2	100	1.000	100	730.0	7.30	0
4	100	1.000	100	630.0	6.30	0
6	100	1.000	100	530.0	5.30	0
8	100	1.000	88.5	430.0	4.30	0
10	77	.770	70	341.5	4.44	0.29
12	63	.630	62	271.5	4.31	0.22
14	61	.610	59.5	209.5	3.43	0.03
16	58	.580	50.5	150.0	2.59	0.05
18	43	.430	36.5	99.5	2.31	0.34
20	30	.300	25	63.0	2.10	0.43
22	20	.200	18	38.0	1.90	0.50
24	16	.160	12.5	20.0	1.25	0.56
26	9	.090	6	7.5	0.83	0.77
28	3	.030	1.5	1.5	0.50	2.00
30	-	-	-	-	-	-

x = age in days

n_x = observed number of larvae surviving at start of age interval x

l_x = proportion surviving at start of age interval

L_x = number of individuals alive on the average during the age interval

T_x = individuals X time units

e_x = mean expectation of further life for larvae alive at start of age x

q_x = rate of mortality

Table IX b : Survivorship table for the larvae of *S. obliqua* on *C. capsularis*

x	n_x	l_x	L_x	T_x	e_x	q_x
0	100	1.00	100	922.0	9.22	0
2	100	1.00	100	822.0	8.22	0
4	100	1.00	100	722.0	7.22	0
6	100	1.00	100	622.0	6.22	0
8	100	1.00	96	522.0	5.22	0
10	92	.92	88.5	426.0	4.63	0.08
12	85	.85	81.5	337.5	3.97	0.08
14	78	.78	73.5	256.0	3.28	0.08
16	69	.69	62.0	182.5	2.64	0.13
18	55	.55	49.0	120.5	2.19	0.25
20	43	.43	38.5	71.5	1.66	0.27
22	34	.34	25	33	0.97	0.26
24	16	.16	8	8	0.50	1.12
26	-	-	-	-	-	-

x = age in days

n_x = observed number of larvae surviving at start of age interval x

l_x = proportion surviving at start of age interval

L_x = number of individuals alive on the average during the age interval.

T_x = individuals X time units

e_x = mean expectation of further life for larvae alive at start of age x

q_x = rate of mortality

Table X a : Stadial duration, consumption (C), egestion (Fu) assimilation (As), production (P) and respiration (R) of S. obliqua larvae reared on fern (D. esculentum) and jute (C. capsularis)(Mean in mg/larva)

Host Plant	Stadial period (days)	Instar	C	Fu	As	P	R
Fern	4	I	1.87	0.11	1.76	0.90	1.67
Jute	4	"	1.11	0.32	0.79	0.09	.70
Fern	4	II	2.65	0.21	2.44	0.17	2.27
Jute	4	"	2.93	1.22	1.70	0.59	1.11
Fern	4	III	6.02	0.82	5.20	0.78	4.42
Jute	4	"	19.62	12.27	7.34	2.50	4.84
Fern	4	IV	26.60	3.93	22.67	4.28	18.39
Jute	4	"	45.78	23.84	21.94	5.21	16.73
Fern	4	V	66.42	10.95	55.47	12.26	43.21
Jute	4	"	97.56	56.57	40.99	10.94	30.05
Fern	4	VI	212.73	43.96	168.77	22.51	146.26
Jute	5	"	644.16	500.42	143.61	55.07	88.54
Fern	5	VII	470.53	335.00	135.53	20.31	115.54
TOTAL							
Fern	29		786.82	394.98	391.84	60.40	331.76
Jute	25		811.16	594.64	216.37	74.40	141.97

Table X b : Relative nutritional indices and efficiencies of *S. obliqua* on fern (*D. esculentum*) and jute (*C. capsularis*) hosts

Host Plant	Instar	Ase	Pe_1	Pe_2	RCR	RGR	R/P	P/A
Fern	I	94.11	4.81	5.11	10.87	.52	18.55	.05
Jute	"	71.17	8.10	11.39	5.55	.45	7.77	.11
Fern	II	92.07	6.41	6.96	5.09	.32	13.35	.06
jute	"	58.02	20.13	34.70	1.62	.32	1.88	.34
Fern	III	86.37	12.95	15.00	3.20	.41	5.66	.15
Jute	"	37.41	12.74	34.05	2.47	.31	1.93	.34
Fern	IV	85.22	16.09	18.87	2.62	.42	4.29	.18
Jute	"	47.92	11.38	23.74	2.78	.31	3.21	.23
Fern	V	83.51	18.45	22.10	2.03	.37	3.52	.22
Jute	"	42.01	11.21	26.68	2.01	.22	2.74	.26
Fern	VI	79.33	10.58	13.33	2.28	.24	6.49	.13
Jute	"	22.29	8.54	38.34	2.58	.21	1.60	.38
Fern	VII	28.80	4.31	14.98	1.15	.04	5.67	.14

Ase = Assimilation efficiency

Pe_1 = Gross production efficiency

Pe_2 = Net production efficiency

RCR = Relative consumption rate

RGR = Relative growth rate

R/P = Maintenance cost

P/A = Production index.

II BIOECOLOGY

A. Spilarctia obliqua (Arctiidae : Lepidoptera)

i. Host plant preference

Food finding and host plant preference experiments of S. obliqua on the five species of ferns indicated that both the early and the late instars of the species showed out and out preference for D. esculentum (Table VII a). No other fern species were consumed in presence of D. esculentum (Fig.12 a,b). In a choice between the most preferred fern D. esculentum, and the angiosperm host, jute (C. capsularis), the early instars showed a clear choice for the latter. In the advanced instars, a higher preference for C. capsularis still persisted (Fig.12c,d). Nevertheless, a reasonable preference was also recorded for D. esculentum by the same larval population. (Table VII b).

ii. Development and performance

S. obliqua females laid profusely when reared on C. capsularis which was about 6-7 times the total eggs laid when reared on D. esculentum (Fig.13). The incubation period of eggs for the adults reared on D. esculentum could not be ascertained as they failed to hatch. On C. capsularis the eggs took about five days to mature and hatchability was almost full (Table VII b)

The larvae of S. obliqua reared on D. esculentum required a longer development period than that on C. capsularis (Fig. 14 a,b,c) . The total period required for prepupal and pupal development stages on both hosts, were very close. In all the three developmental stages i.e. larvae, pupae and adults, a higher percentage of survival was recorded on C. capsularis than that on D. esculentum, on which the larvae showed an additional instar. Although a great difference was not observed on the female longevity yet clearly a higher longevity in males was noted on C. capsularis than on D. esculentum (Table VIIIb; Fig.15,16 a,b). Dry weight of pupae and adult females as expected were higher than that of males on both hosts. However, both pupal and adult weights were higher on C. capsularis when compared to the ones on D. esculentum. Almost a threefold increase in adult emergence was noted on C. capsularis as compared to that on D. esculentum (Table VIII a)

iii. Survivorship study

The survivorship curves of the larvae of S. obliqua showed no mortality for the first week on both C. capsularis (jute) and fern hosts. This was followed by an increase in death rate till 22 day on jute and 26 day on fern (Table IX a,b). In the last phase i.e. on 24th day on jute and 28th day on the fern (D. esculentum) there was an abrupt increase in the death rate which was more on the latter than the former. In the prepupal stage, the l_x values on jute was recorded to be higher than that on Diplazium. However, in both the survivorship curves, a generalised Type I (after Pearl, 1928) curve was observed which indicates that the population had very little death in most of its early life span and then high losses in the older stages (Fig. 17 a,b).

iv. Dry weight (mass) budget of larvae on fern and jute :

a. Consumption, egestion and weight gain

The degree of consumption, faeces produced and weight gained by the larvae increased in subsequent instars on both host plants (Table X a). The total consumption and egestion were more on C. capsularis (jute) than that on fern. The total production was found to be lower on fern as compared to that on jute. On fern, the relative consumption rate(RCR) decreased steadily with advancement of larval instars. This value varied among instars when fed on jute (Fig.18a).However, total consumption of fern (I-VII instars) was higher as compared to that of jute. Total production or growth was higher on jute but during the additional instar (VII) on fern, a weight gain of almost 1/3 times of the total weight took place. A gradual decrease in the RGR was recorded on jute while the values showed variation on fern. (Fig. 18b).

b. Assimilation and respiration:

Total values of assimilation and respiration on fern by far exceeded that on jute (Table X a). In most of the instars, the As and R values were higher on fern. More than about half the total values of As and R on fern were recorded during the VII instar. In general, the cost of maintenance (R/P) of the earlier larval instar was higher on both the hosts but it was much more on fern as compared to one on jute (Fig. 19a).

Fig.20a. **Intact frond of fern host D. esculentum of S. casigneta.**

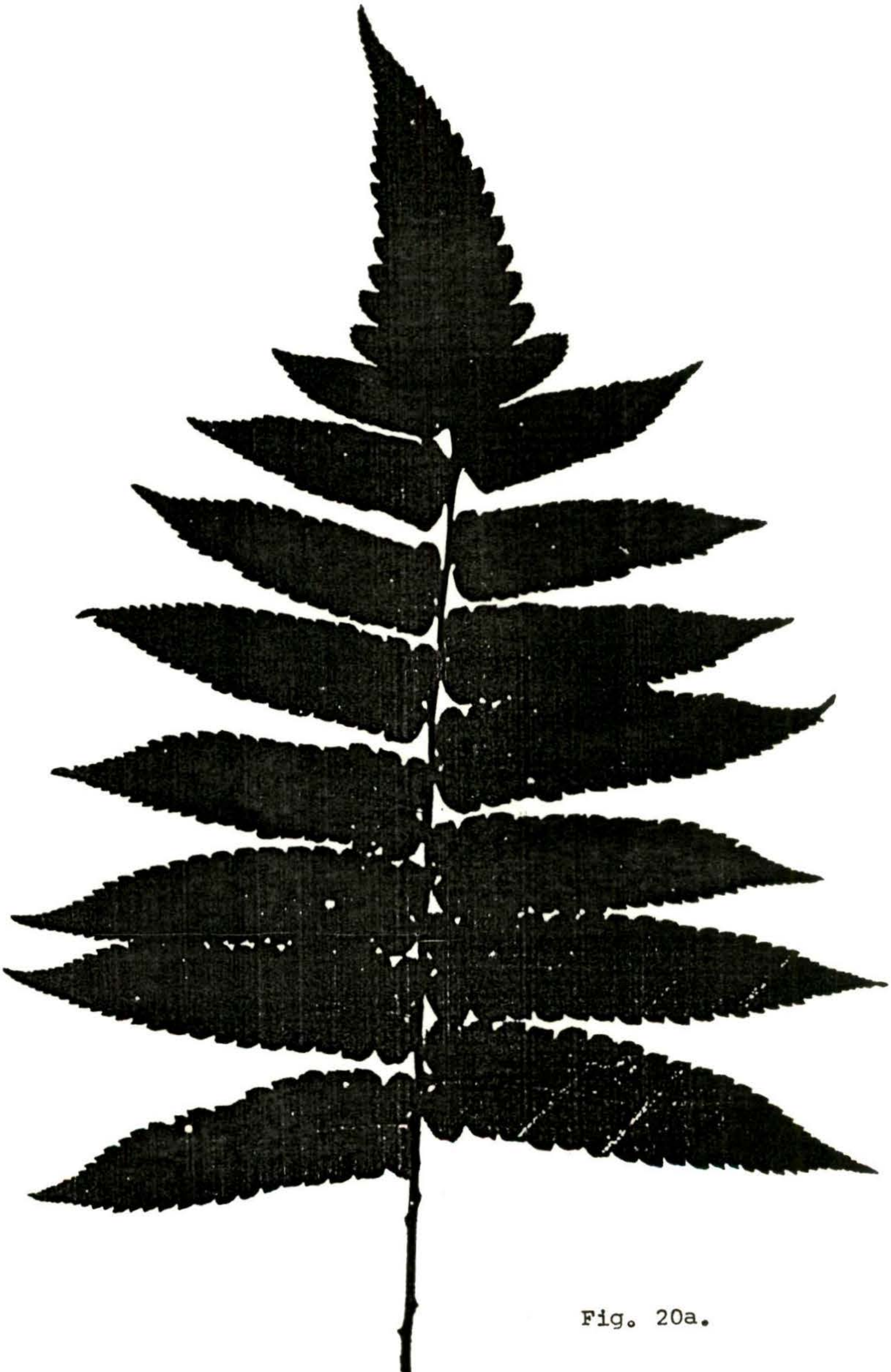


Fig. 20a.

Fig. 20b. Remaining part of _D. esculentum_ frond after feeding by late instar larvae of _S. casigneta_.

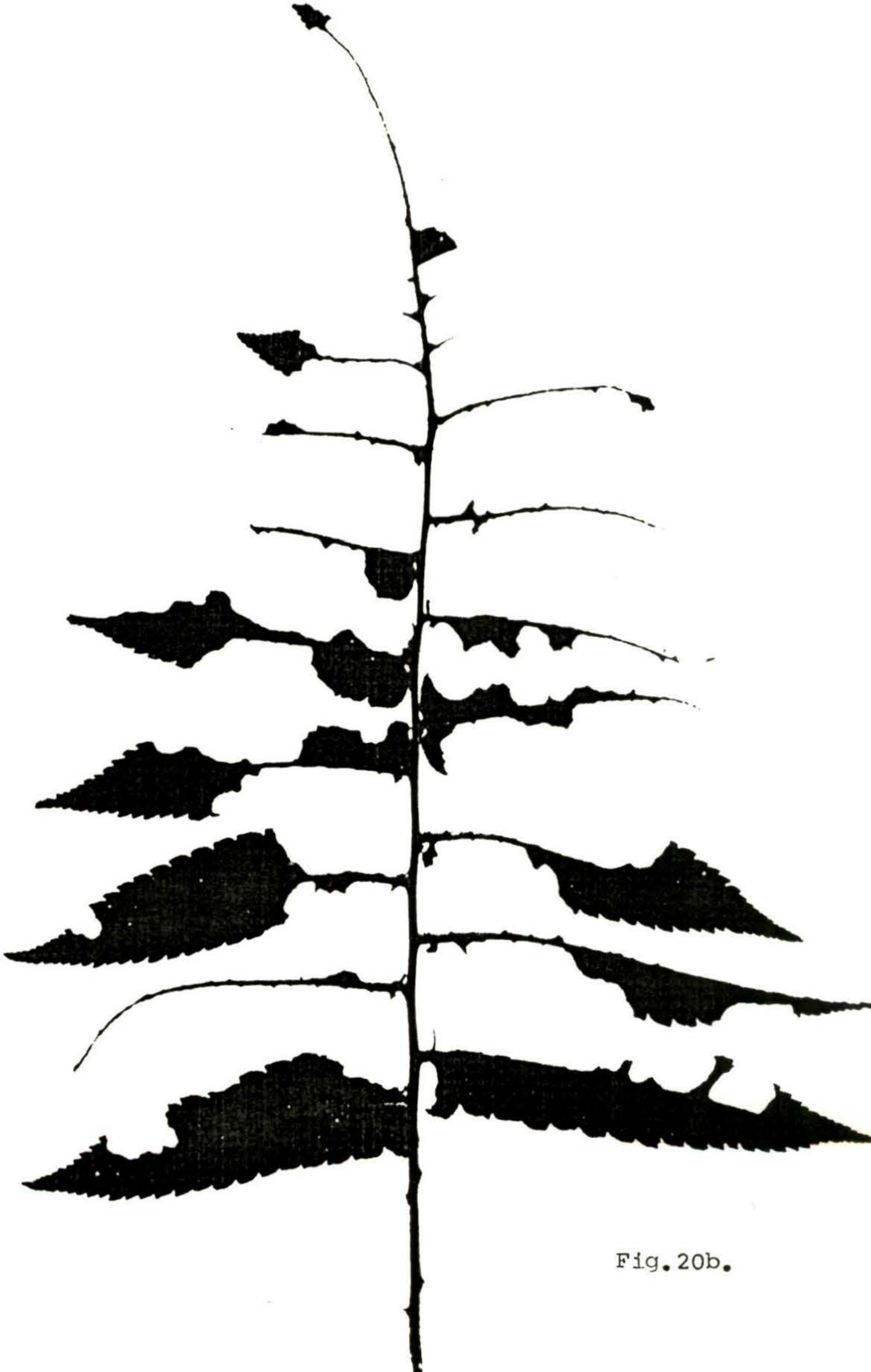


Fig.20b.

Fig. 20c. Intact leaf of angiosperm host (*M. indica*) of *S. casigneta*.

Fig. 20d. **Remaining part of** *M. indica* leaf after feeding by late instar larvae of *S. casigneta*.

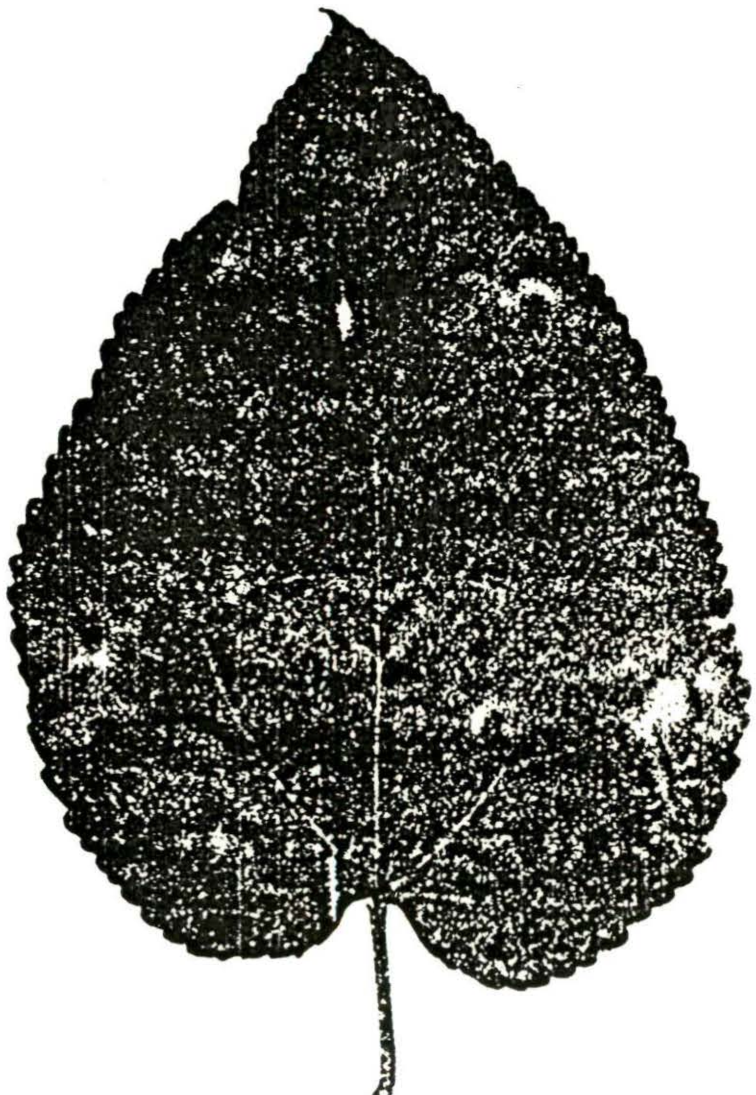


Fig. 20c.

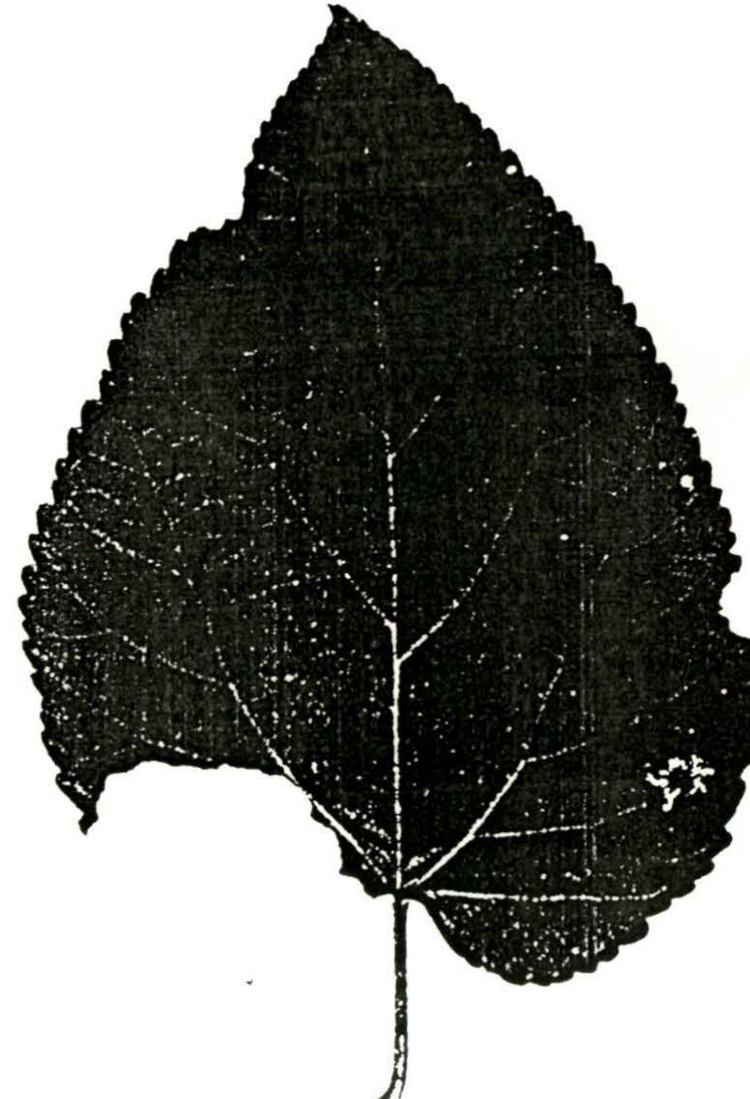


Fig. 20d.

Table XI a,b. Host plant preference by <u>Spilarctia</u> <u>casigneta</u> calculated in percentage of leaf area consumed/ insect/hour.

a.

	FERNS				
Stage	D.esculentum	C.crinipes	M.speluncae	L.ensifolia	D.linearis
Early larva	0.17	-	-	-	-
Advanced larva	1.29	-	-	-	-

b.

	FERN - ANGIOSPERM	
Stage	D. esculentum	M. indica
Early larva	0.70	-
Advanced larva	1.29	0.23

Fig. 21. Eggs of S. casigneta on D. esculentum.

Fig. 22a (i). Early instar larvae of S. casigneta on D. esculentum.

Fig. 22a (ii). Skeletonised leaves of D. esculentum by larvae of S. casigenta.

Fig. 21.

Fig. 22a (i)

Fig. 22a (ii)

Fig. 22b. IV instar larvae of *S. casigneta* on *D. esculentum*.

Fig. 22c. Late instar larvae of *S. casigneta* on *D. esculentum*.

Fig. 22b.

Fig. 22c.

Fig. 23a. Early instar larvae of *S. casigneta* on *M. indica*.

Fig. 23b. Late instar larvae of *S. casigneta* on *M. indica*.

Fig. 23a.

Fig. 23b.

Fig. 24. Pupation of _S_. _casigneta_ on fern _D_. _esculentum_.

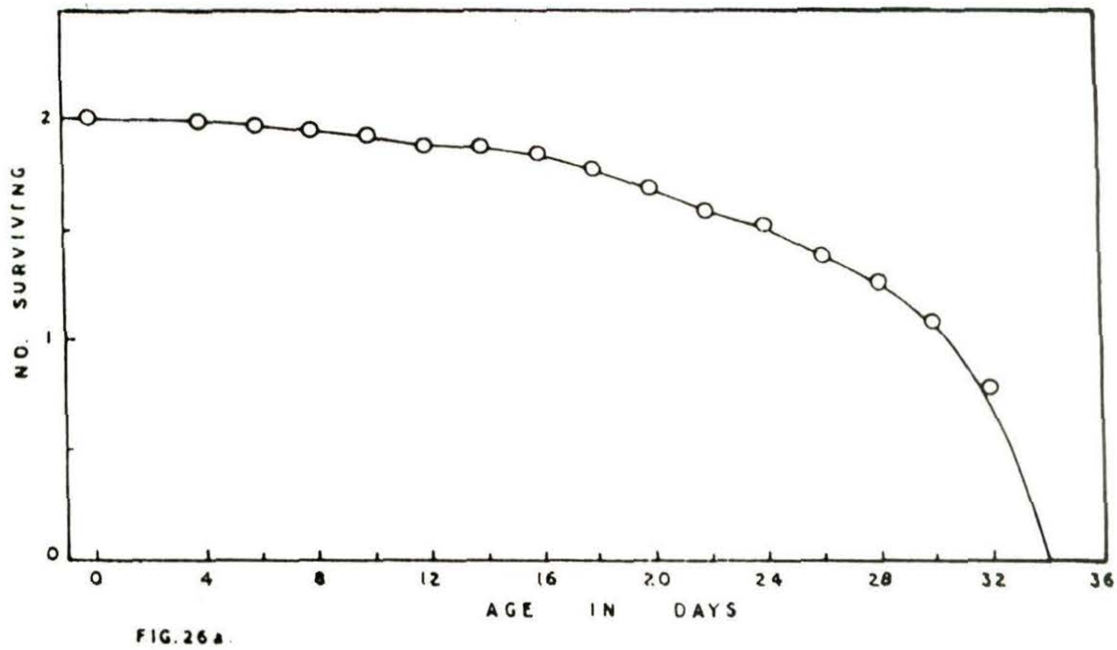
Fig. 25a. Female of _S_. _casigneta_ on _D_. _esculentum_.

Fig. 25b. Male of _S_. _casigneta_ on _D_. _esculentum_.

Fig. 24.

Fig. 25a.

Fig. 25b.



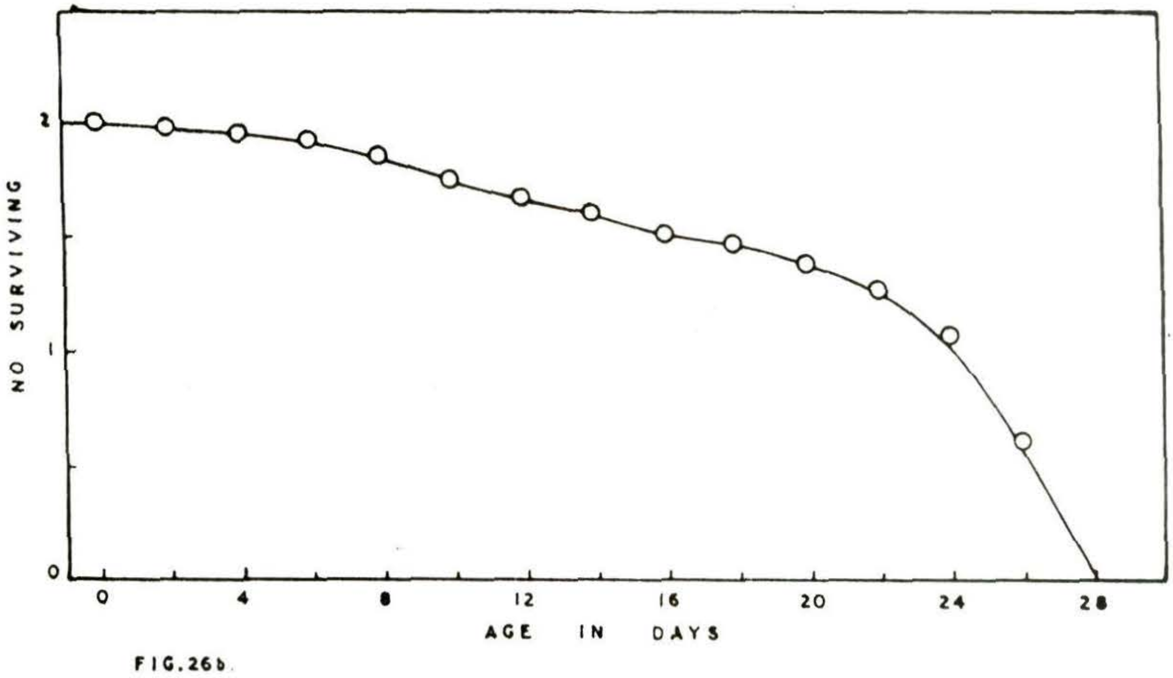
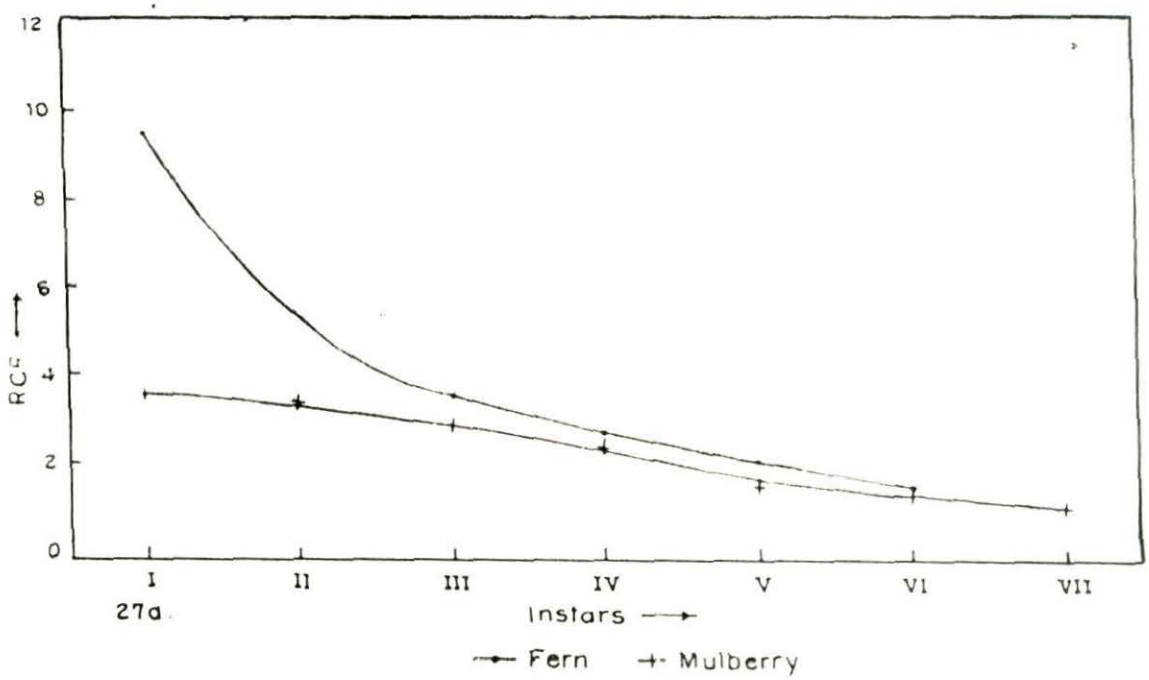


Fig.26a. Survivorship curve of S. casigneta on D. esculentum .

Fig.26b. Survivorship curve of S. casigneta on M. indica.



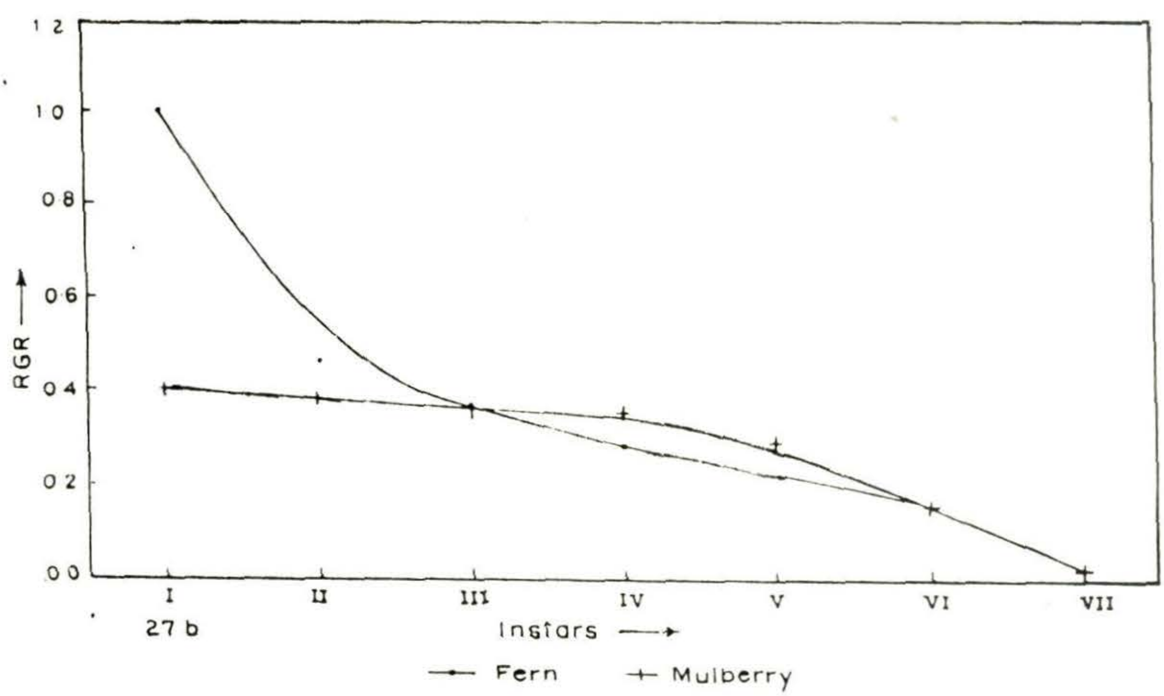
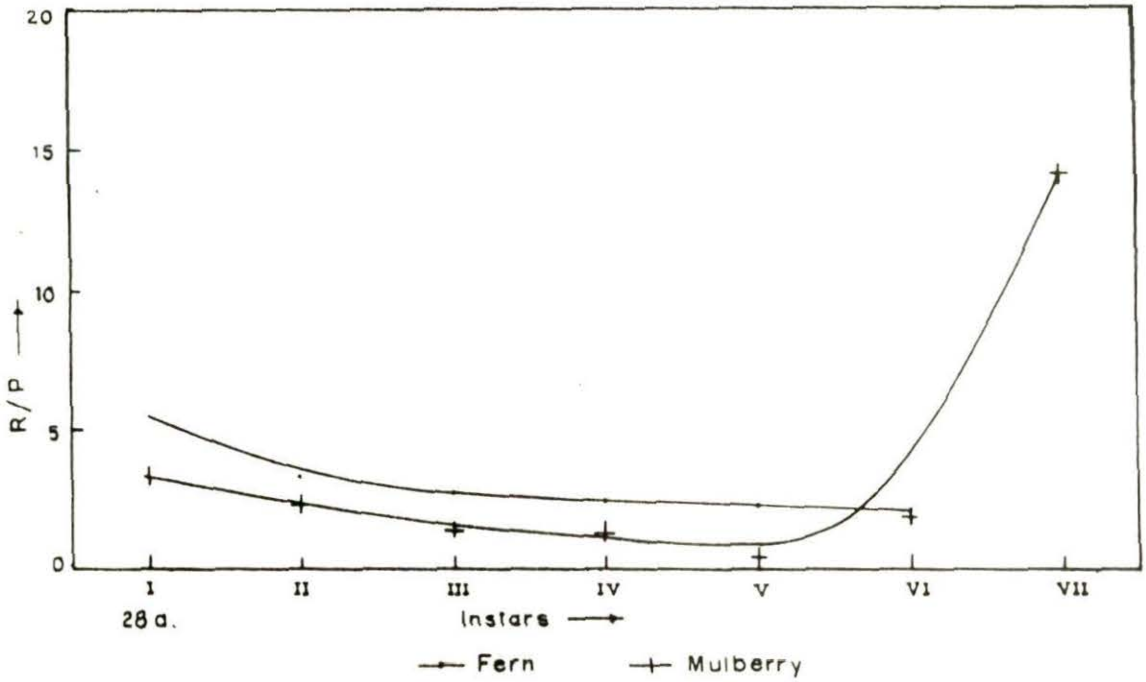


Fig. 27a. Relative consumption rate of different larval stages of S. casigneta on D. esculentum and M. indica.

Fig. 27b. Relative growth rate of different larval stages of S. casigneta on D. esculentum and M. indica.



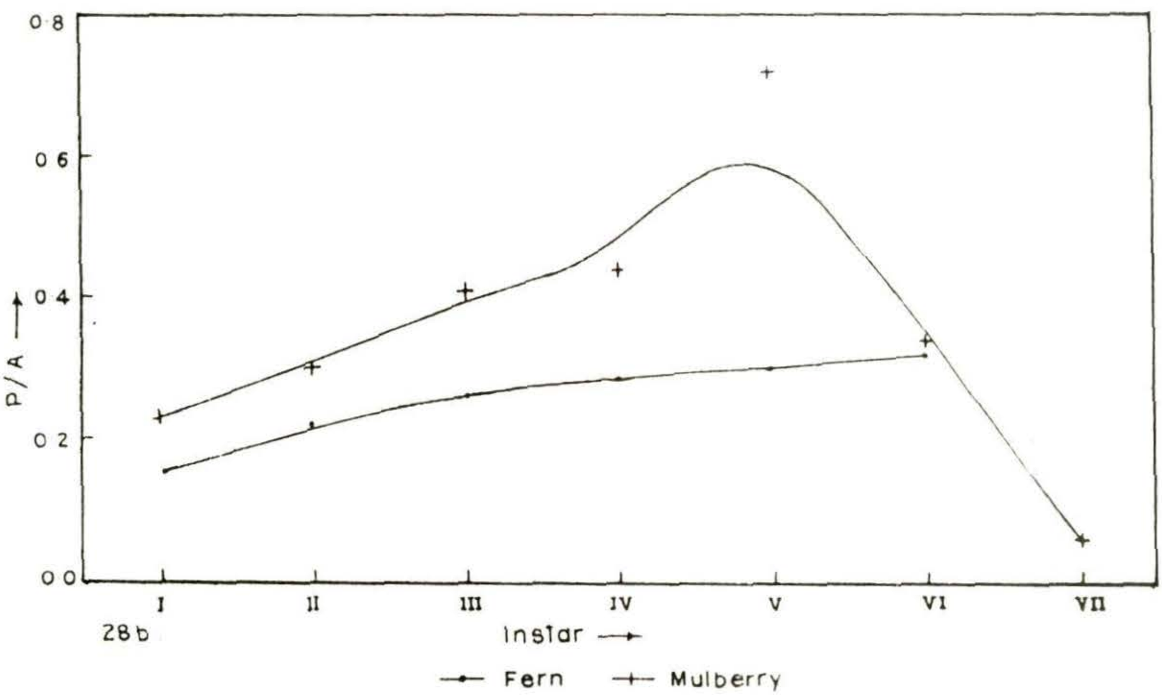


Fig. 28a. Comparison of maintenance cost (R/P) of different larval stages of *S. casigneta* on *D. esculentum* and *M. indica*.

Fig. 28b. Comparison of production index (P/A) of different larval stages of *S. casigneta* on *D. esculentum* and *M. indica*.

Table XII a. Performance of _S. casigneta_ on fern (_D. esculentum_) and angiosperm (_M. indica_) hosts (mean ± SD)

Host Plant	Pupal dry wt. (mg) Male	Pupal dry wt. (mg) Female	Adult emergence (%)	Adult dry wt. (mg) Male	Adult dry wt. (mg) Female	Longevity (days) Male	Longevity (days) Female	Fecundity
Diplazium esculentum	47.97 ± 1.48	98.37 ±1.07	89.11 ±1.71	45.98 ±1.03	97.07 ±1.22	5.18 ±0.26	8.36 ±0.84	683.75 ±65.62
Morus indica *		--	--	--	--	--	--	--

* not covered in the present study

Table XII b. Duration (days) and survival (%) of different stages of *S. casigneta* on fern (*D. esculentum*) and angiosperm host (*M. indica*) Mean ± SD

Stage	P- Period (days) S- Survival (%)	HOST PLANT	
		D. esculentum	*M. indica*
Larvae	P	1 - 28	1 - 26
	S	28.83 ± 1.79	4.66 ± 1.24
Prepupal	P	29 - 31	27 - 29
	S	27.15 ± 1.40	3.33 ± 1.69
Pupal	P	32 - 44	30 - 39
	S	24.56 ± 1.36	00.66 ±0.47
Egg	P	0 - 4	---
	S*	92.48 ± 0.43	

* Hatchability

Table XIII a : Survivorship table for the larvae of *S. casigneta* on *D. esculentum*

x	n_x	l_x	L_x	T_x	e_x	q_x
0	100	1.00	100	973	9.73	0
2	100	1.00	99	673	8.73	0
4	98	.98	96.5	774	7.89	.02
6	95	.95	92	677.5	7.13	.03
8	89	.89	87	585.5	6.58	.06
10	85	.85	82	498.5	5.86	.04
12	79	.79	77	416.5	5.27	.07
14	75	.75	71.5	339.5	4.53	.05
16	68	.68	63	268	3.49	.10
18	58	.58	52.5	205	3.54	.17
20	47	.47	42.5	152.5	3.24	.23
22	38	.38	35	110	2.89	.23
24	32	.32	27.5	75	2.34	.18
26	23	.23	20.5	47.5	2.07	.39
28	18	.18	15	27	1.50	.27
30	12	.12	9	12	1.00	.50
32	6	.06	3	3	.50	1.00
34	-	-	-	-	-	-

x = age in days

n_x = observed number of larvae surviving at start of age interval x

l_x = proportion surviving at start of age interval

L_x = number of individuals alive on the average during the age interval

T_x = individuals x time units

e_x = mean expectation of further life for larvae alive at start of age x

q_x = rate of mortality

Table XIII b : Survivorship table for the larvae of *S. casigneta* on *M. indica*.

x	n_x	l_x	L_x	T_x	e_x	q_x
0	100	1.00	98	660	6.60	0
2	96	.96	93.5	562	5.85	.04
4	91	.91	87.5	468.5	5.14	.05
6	84	.84	78	381	4.54	.08
8	72	.72	64.5	303	4.21	.01
10	57	.57	52	238.5	4.18	.02
12	47	.47	43.5	186.5	3.97	.21
14	40	.40	36.5	143	3.58	.11
16	33	.33	31.5	106.5	3.23	.21
18	30	.30	27.5	75	2.50	.10
20	25	.25	22	47.5	1.90	.20
22	19	.19	15.5	25.5	1.34	.31
24	12	.12	8	10	0.83	.58
26	4	.04	2	2	0.50	2.00
28	-	-	-	-	-	-

x = age in days

n_x = observed number of larvae surviving at start of age interval x

l_x = proportion surviving at start of age interval

L_x = number of individuals alive on the average during the age interval

T_x = individuals x time units

e_x = mean expectation of further life for larvae alive at start of age x

q_x = rate of mortality

Table XIV a : Stadial duration, consumption (C), egestion (Fu), assimilation (As), production (P) and respiration (R) of S. casigneta reared on fern (D. esculentum) and mulberry (M. indica) hosts (Mean in mg/larva)

Host Plant	Stadial Period	Instar	C	Fu	As	P	R
Fern	2	I	3.60	1. 4	2.46	.38	2.08
Mul.	2	"	2.33	1.17	1.16	.27	.89
Fern	2	II	12.76	6.89	5.87	1.35	4.52
Mul.	3	"	9.55	5.87	3.68	1.12	2.56
Fern	4	III	42.75	25.80	16.95	4.53	12.42
Mul.	3	"	25.91	16.88	9.03	3.75	5.28
Fern	4	IV	120.33	76.26	44.07	12.82	31.25
Mul.	4	"	83.02	54.63	28.39	12.61	15.78
Fern	4	V	628.85	408.76	220.09	67.16	152.93
Mul.	4	"	130.12	96.60	33.52	24.33	9.19
Fern	6	VI	984.53	663.40	321.13	105.88	222.25
Mul.	5	"	373.67	248.23	125.44	43.94	81.50
Mul.	3	VII	444.93	300.29	144.69	9.49	135.20
<u>TOTAL</u>							
Fern			1792.28	1182.25	610.57	192.12	425.45
Mul.			1069.53	722.67	345.91	95 .51	250.40

Mul. = Mulberry

Table XIV b : Relative nutritional indices and efficiencies of *S. casigneta* on fern (*D. esculentum*) and mulberry (*M. indica*) hosts

Host Plant	Instar	Ase	Pe_1	Pe_2	RCR	RGR	R/P	P/A
Fern	I	68.33	10.55	15.44	9.47	1.00	5.47	.15
Mul.	"	49.78	11.58	23.27	3.53	.40	3.29	.23
Fern	II	46.00	10.57	22.99	4.40	.46	3.34	.22
Mul.	"	38.53	11.72	30.43	3.31	.38	2.28	.30
Fern	III	39.64	10.59	20.72	3.49	.37	2.74	.26
Mul.	"	34.85	14.47	41.52	2.81	.35	1.40	.41
Fern	IV	36.62	10.65	29.09	2.65	.28	2.43	.29
Mul.	"	34.19	15.18	44.41	2.36	.35	1.25	.44
Fern	V	34.99	10.67	30.51	2.07	.22	2.27	.30
Mul.	"	25.16	18.69	94.44	1.55	.29	.37	.72
Fern	VI	32.61	10.75	32.97	1.52	.16	2.07	.32
Mul.	"	33.56	11.75	35.02	1.33	.15	1.85	.34
Mul.	VII	32.51	2.13	6.55	1.10	.02	14.24	.06

Mul. = Mulberry

Ase = Assimilation efficiency

Pe_1 = Gross production efficiency

Pe_2 = Net production efficiency

RCR = Relative consumption rate

RGR = Relative growth rate

R/P = Maintenance cost

P/A = Production index

c. Efficiency values :

Assimilation efficiency (Ase) was found to be higher in all instars on fern. On jute the gross production efficiency (Pe_1) was higher in earlier instars but in advanced instars the trend reversed in favour of fern. Contrastingly, the net production efficiency (Pe_2) and production index (P/A) on jute was consistently higher in all the instars (Fig. 19 b). A significant decline in the P/A value was observed during the additional instar on fern (Table Xb).

B. Spilarctia casigneta (Arctiidae : Lepidoptera)

i. Host plant preference

In a similar host-plant preference experiment with both early and advanced instars of S. casigneta, using five species of ferns, a clear preference for D. esculentum was observed. No feeding damage was recorded for any other fern species. Leaf area of D. esculentum consumed by advanced instar was about (Fig. 20a,b) 7-8 times of that of the earlier (Table XI a). The data on preference between D. esculentum and the angiosperm host, mulberry (M. indica), showed a clear choice for the fern plant by the early instar. In the advanced instar, a similar choice was apparent (Fig. 20c,d). However, some amount of consumption of M indica leaves was also observed (Table XIb). The advanced instar showed a higher consumption (5-6 times) of D. esculentum when compared to the early instars.

ii. Development and performance

S. casigneta females were found to have a fair fecundity on D. esculentum (Fig.21) (Table XIIa). Incubation period of eggs on D. esculentum was about four days and no observation on mulberry could be made since a few females that emerged failed to lay eggs. On the fern plant, the egg hatchability was quite high (Table XII b). The larval development on D. esculentum took a slightly longer period (Fig. 22 a,b,c) than on M. indica (Fig.23 a,b). The total period required for prepupal and pupal development showed a large difference (Fig. 24). Approximately 1/3 of the total population reached late larval, prepupal and pupal stages on D. esculentum. On the same host less mortality was recorded than that on M. indica . Female longevity exceeded that of male. Pupal and adult weights of females were higher that that of males(Fig. 25 a,b). Almost a 90% successful adult emergence was recorded on the fern host. Performance of S. casigneta on M. indica was by and large unsatisfactory although larval growth and development took place. Final pupation of only a few were noted. In an unfortunate incident most of the cocoons and pupae were attacked by some ants inside the B.O.D. leading to their depredation. As such no proper weight of the pupae and adult could be recorded.

iii. Survivorship study :

The survivorship curve for the larvae of S. casigneta showed no mortality on D. esculentum for the first week (Fig.26 a). This was followed by a gradual increase in death till 28th day. In the last period i.e. from 22 to 32 days, the few left had a better survival. The death rate, however, showed variation with a sudden increase on 16th, 28th, 30th and 32nd day on D. esculentum (XIII a). The death of S. casigneta larvae on M. indica started at an early stage and increased gradually till 10th day (Fig.26b). From 12th day onwards with some variation both the number of deaths and the death rate increased steeply which reached its climax on the 26th or in the last few days of larval life (Table XIII b). A comparision of '1_x' values for the larval survival ultimately showed that more of the larvae entered pupation on D. esculentum host than on M. indica.

The survivorship curve of S. casigneta on D. esculentum showed more or less the Type I curve of Pearl (1928). Survivorship curve of the larvae of the same on M. indica host ,however, showed variation and ranked between Type I and Type II. (Fig. 6)

iv. Dry weight (mass) budget of larvae on fern and mulberry.

a. Consumption, egestion and weight gain

The ingestion of host plants, degree of egestion and gain in body weight by the larvae of S. casigneta showed considerable variation from instar to instar. The amount of leaf eaten by a larvae during its total feeding periods was 1792.28 mg and 1069.53 mg. of D. esculentum and M. indica (mulberry) respectively. Similarly, higher values for egestion (Fu) and production (P) were recorded on fern as compared to mulberry (Table XIV a). The relative consumption rate (RCR) was highest in the first instar, the value being notably higher on fern. This decreased steadily in the subsequent instars on both the hosts (Fig. 27a). In general, the RCR was slightly higher on fern as compared to one on mulberry. The relative growth rate (RGR) in the subsequent instars on both the host plants showed a decreasing trend. There was a sudden decrease in the RGR value in fern from the Ist to IInd instar (Fig. 27b).

b. Assimilation and Respiration

The total values for assimilation and respiration were little more than double on ferns as compared to mulberry (Table XIV a). In all the instars, the As and R values on fern by far exceeded that on mulberry. The cost of maintenance (R/P) was also much higher in the early instars on both the host plants (Fig. 28a). In general, R/P values were higher on fern than that on mulberry, but a sharp rise in the maintenance cost of VII instar was noted on the latter host.

c. Efficiency values :

The assimilation efficiency (Ase) decreased steadily with the advancement of larval instars on fern. These values showed a variation among different instars when fed on mulberry. For all instars, the gross production

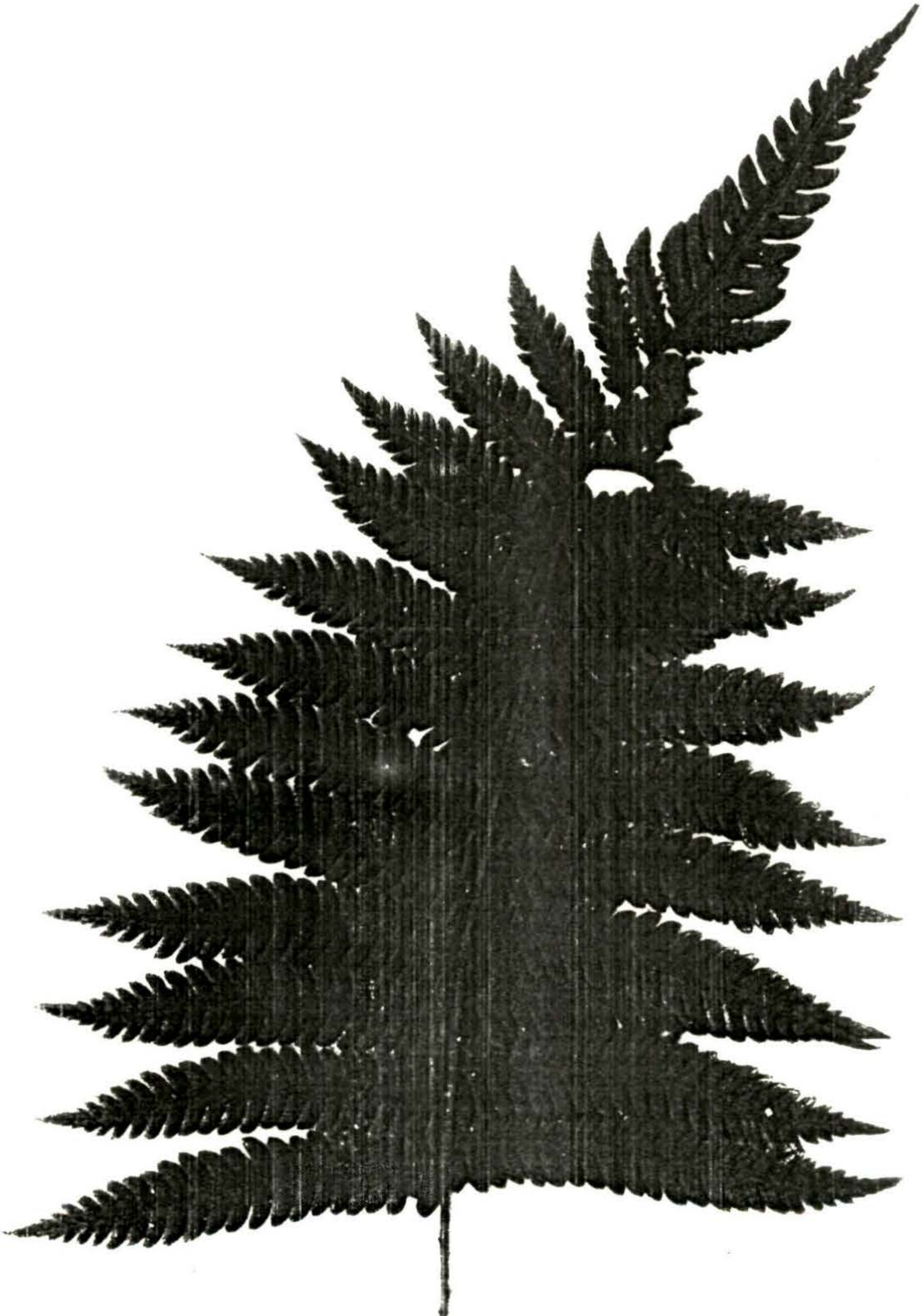


Fig. 29a. Intact frond of the fern host, C. crinipes of A. crenulata.

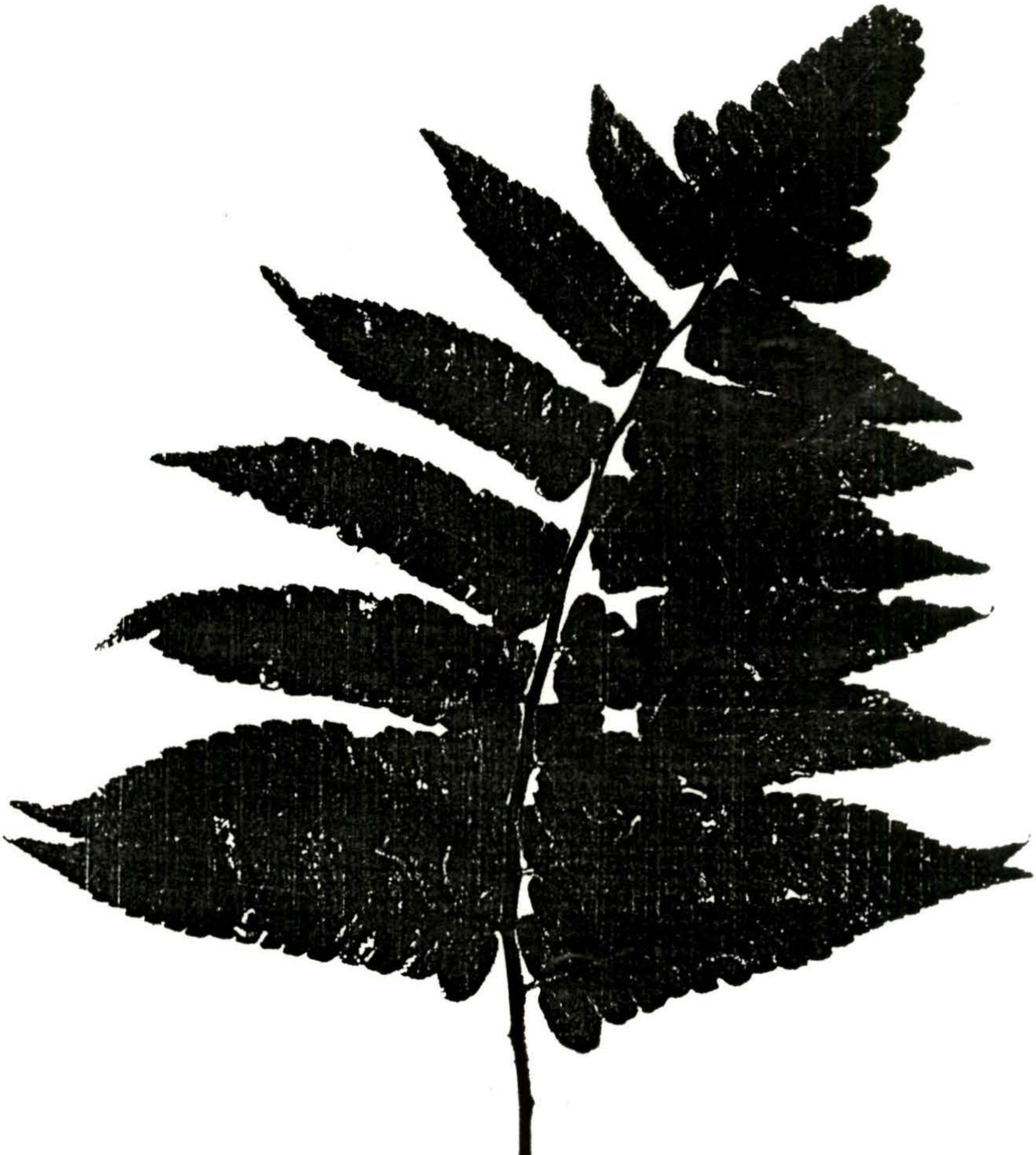


Fig. 29b. Intact frond of the fern host D. esculentum of A. crenulata.

Fig.29c. Remaining part of C. crinipes after feeding by late instar A. crenulata nymphs.

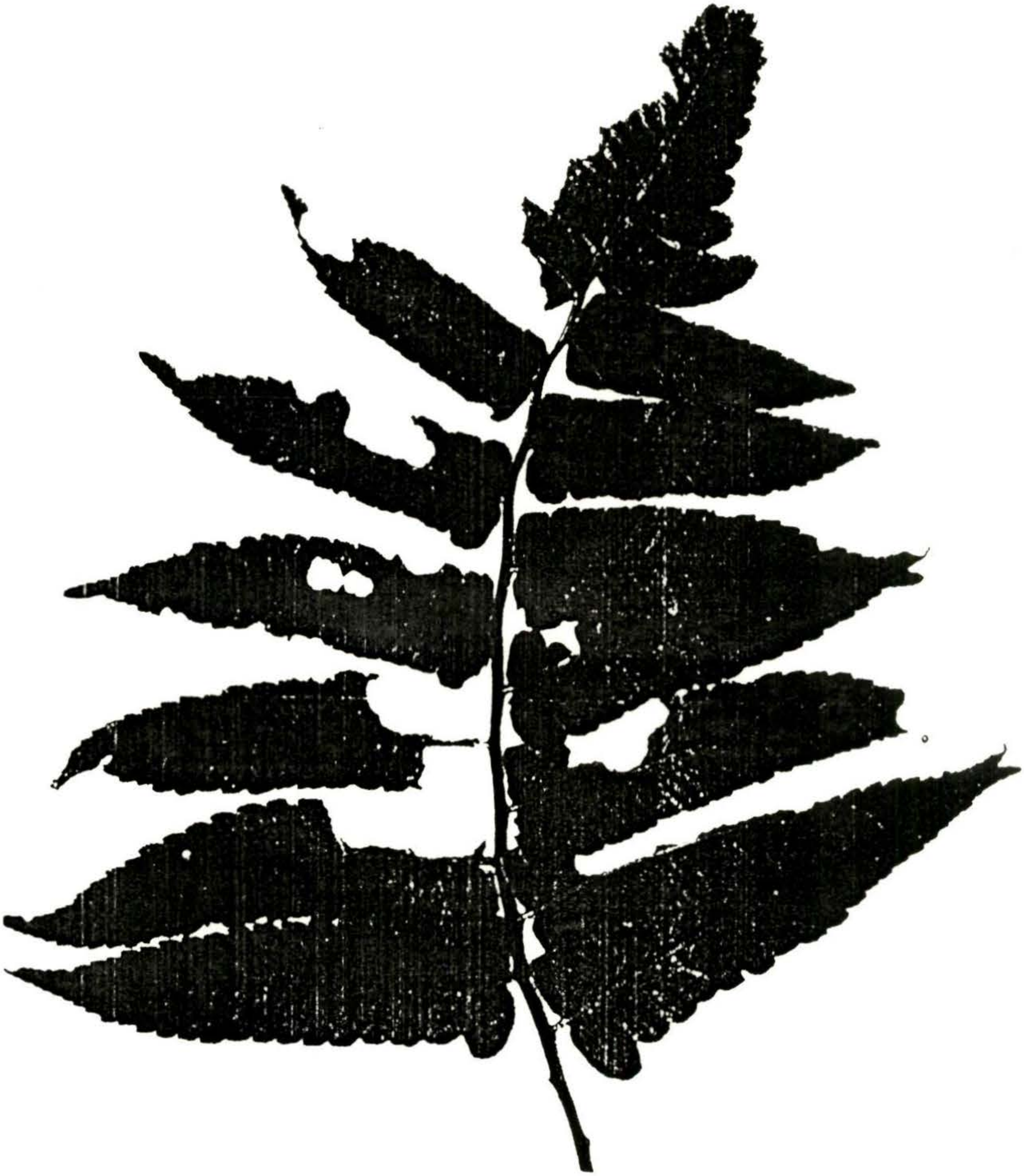


Fig. 29d. Remaining part of D. esculentum after feeding by late instar nymphs of A. crenulata .

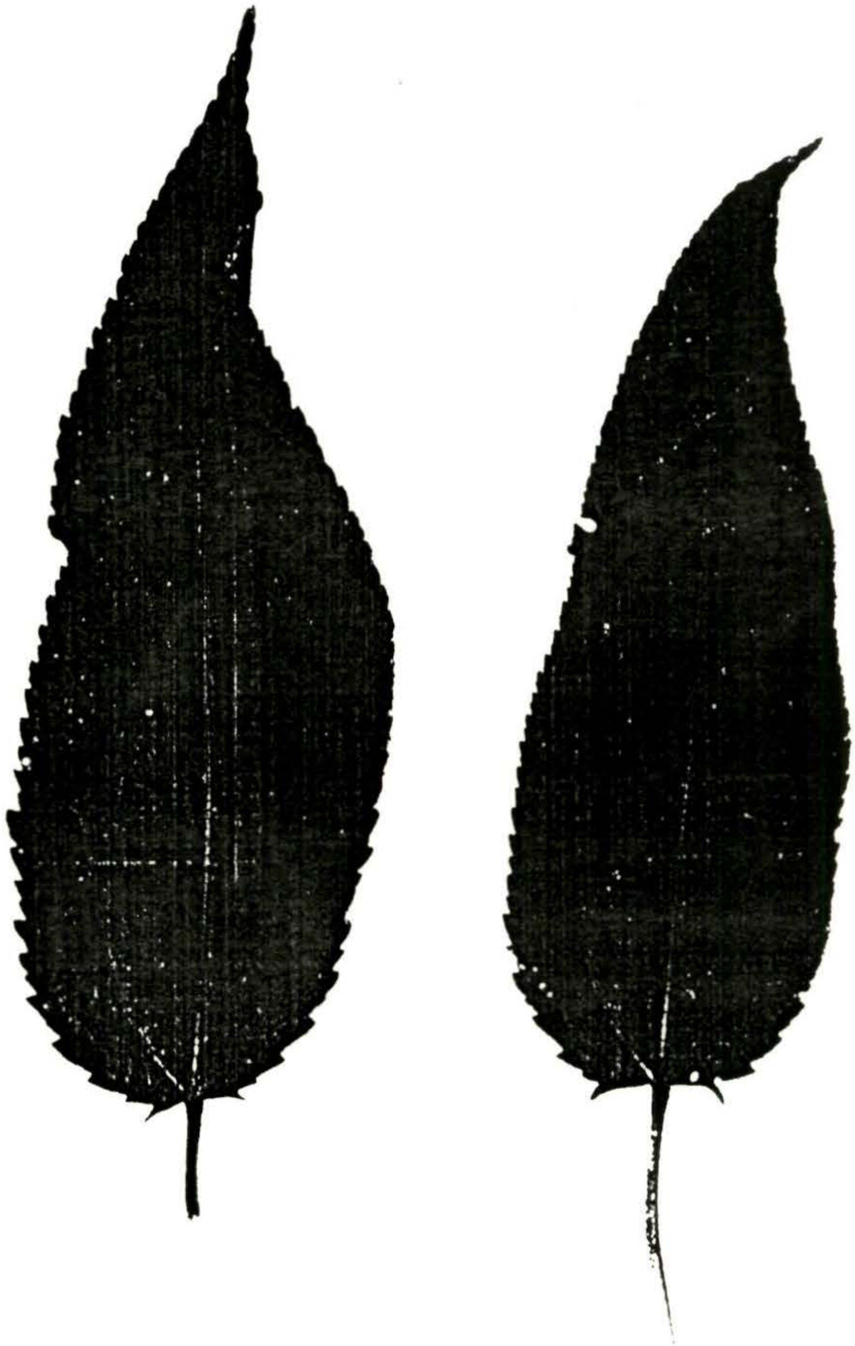


Fig.30a. Intact leaves of angiosperm host , C. capsularis of A. crenulata.

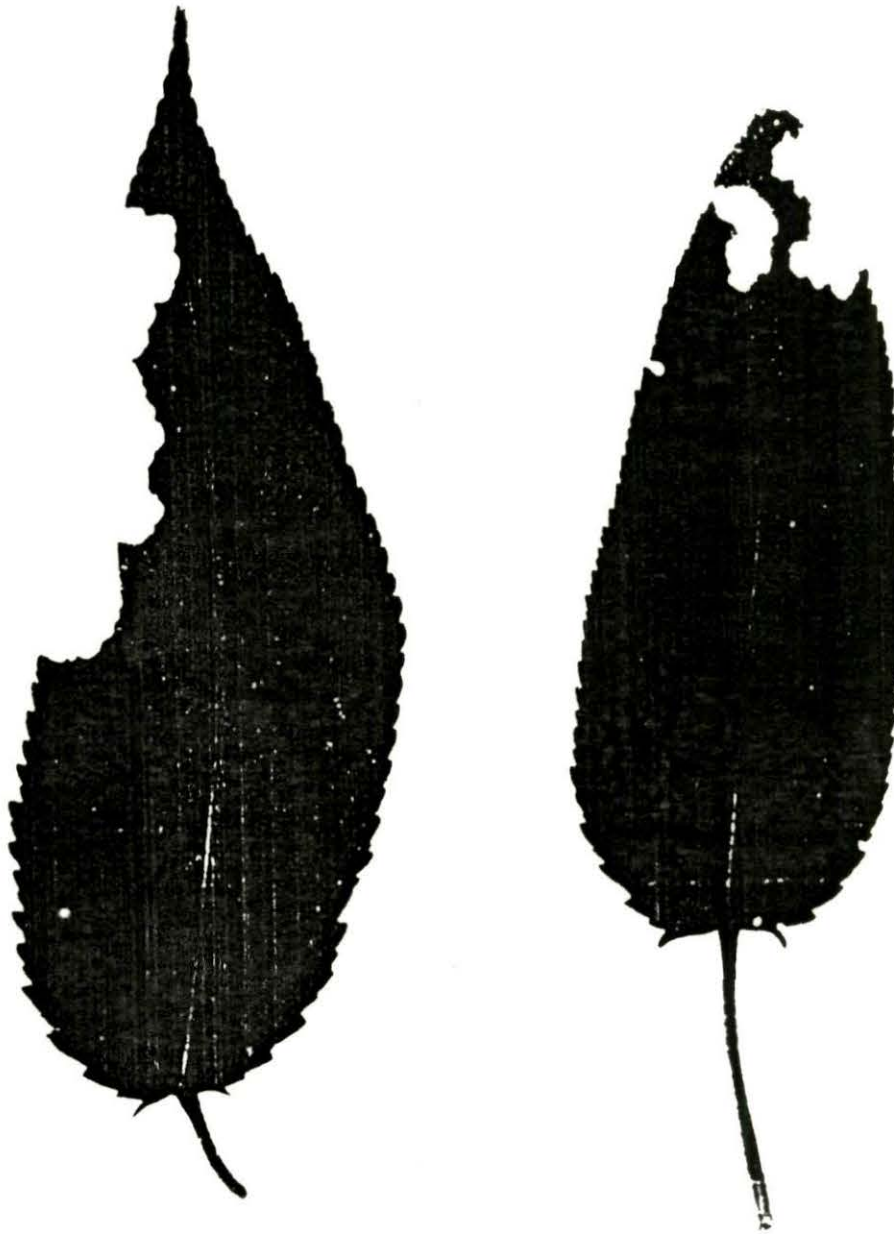


Fig.30b. Leaves of *C. capsularis* after feeding by late instar nymphs of *A. crenulata*.

Table XV a,b. Host plant preference by *Atractomorpha crenulata* calculated in percentage of leaf area consumed/insect/hour.

a.

	FERNS				
Stage	*C. crinipes*	*D. esculentum*	*L. ensifolia*	*M. speluncae*	*D. linearis*
Early nymphs	0.08	0.06	-	-	-
Advanced nymphs	0.45	0.30	-	-	-
Adult	0.23	0.23	-	-	-

b.

	FERN - ANGIOSPERM	
Stage	*C. crinipes*	*C. capsularis*
Early nymph	0.12	0.07
Advanced nymph	0.85	0.20
Adult	0.41	0.34

Fig.31. Eggs of *A. crenulata*.

Fig.32a. Early nymphs of *A. crenulata* on *C. capsularis*.

Fig. 31.

Fig. 32a.

Fig.32b. V instar male of A. *crenulata*.

Fig.32c. VI instar female of A. *crenulata*.

Fig.33. Mating pair of A. *crenulata*.

Fig.32b.

Fig.32c.

Fig.33.

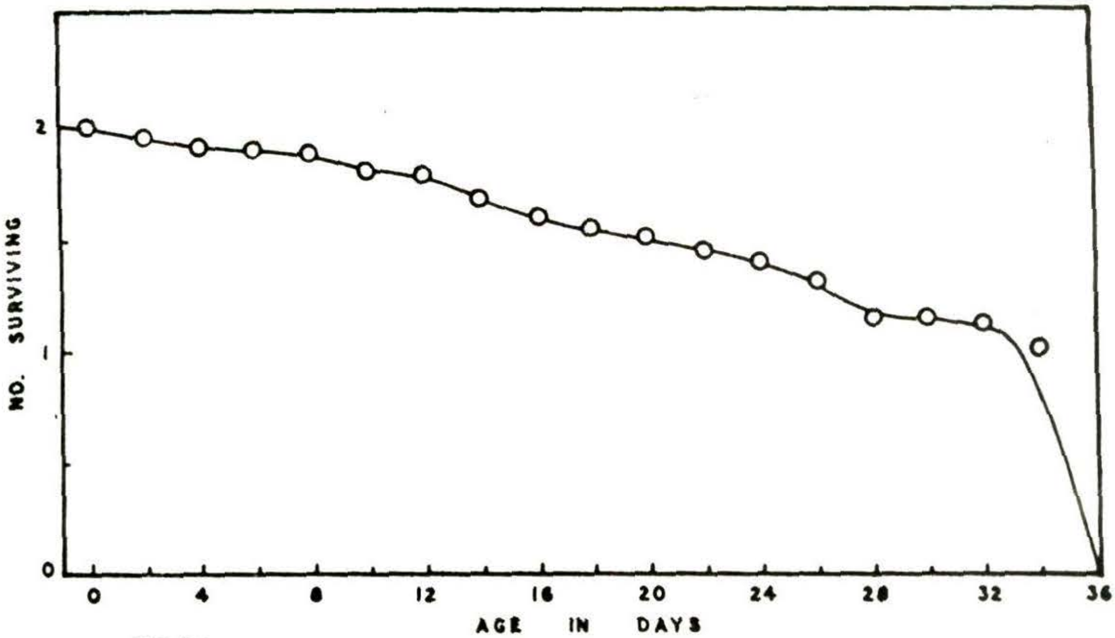


FIG. 34a.

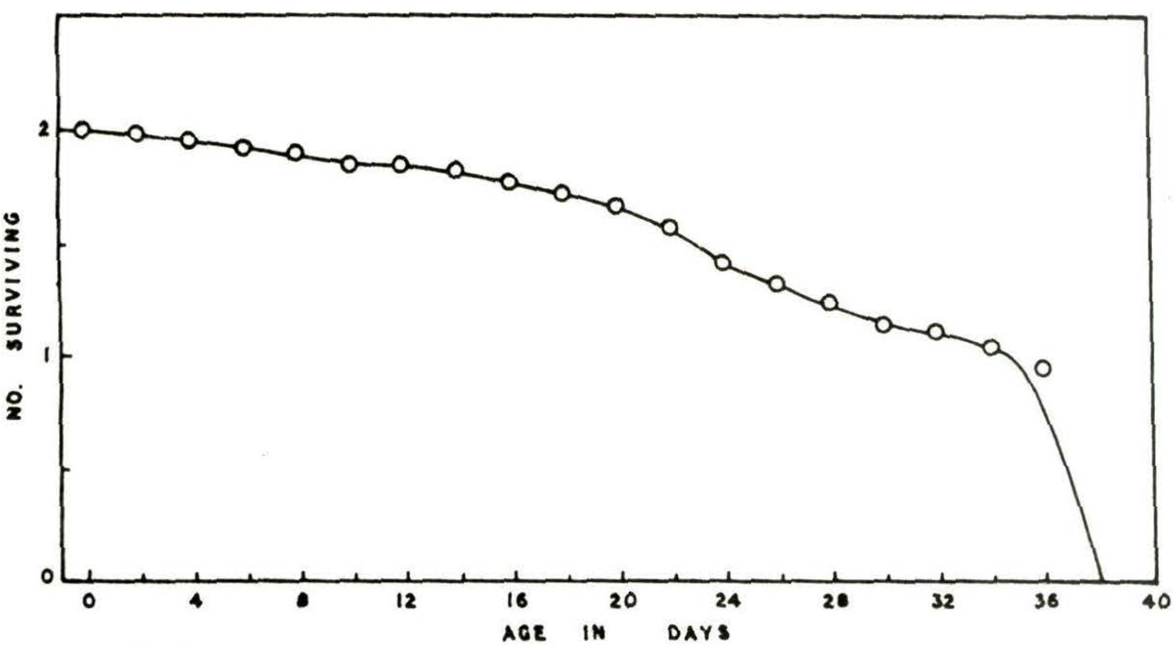


FIG. 34b.

Fig. 34a. Survivorship curve of A. crenulata on C. crinipes.

Fig. 34b. Survivorship curve of A. crenulata on C. capsularis.

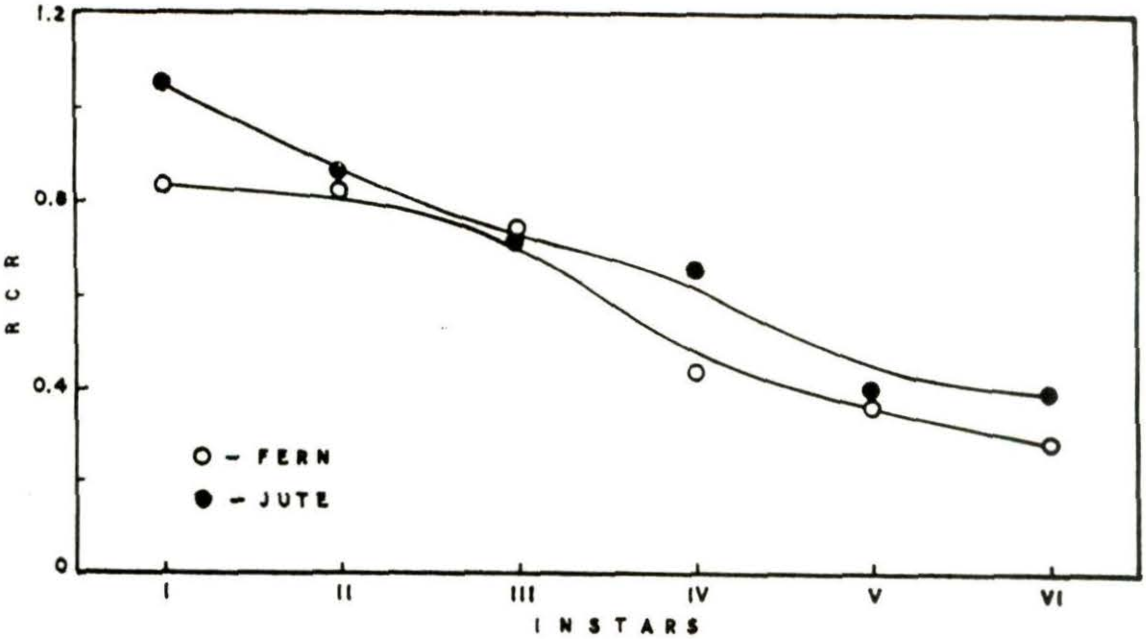
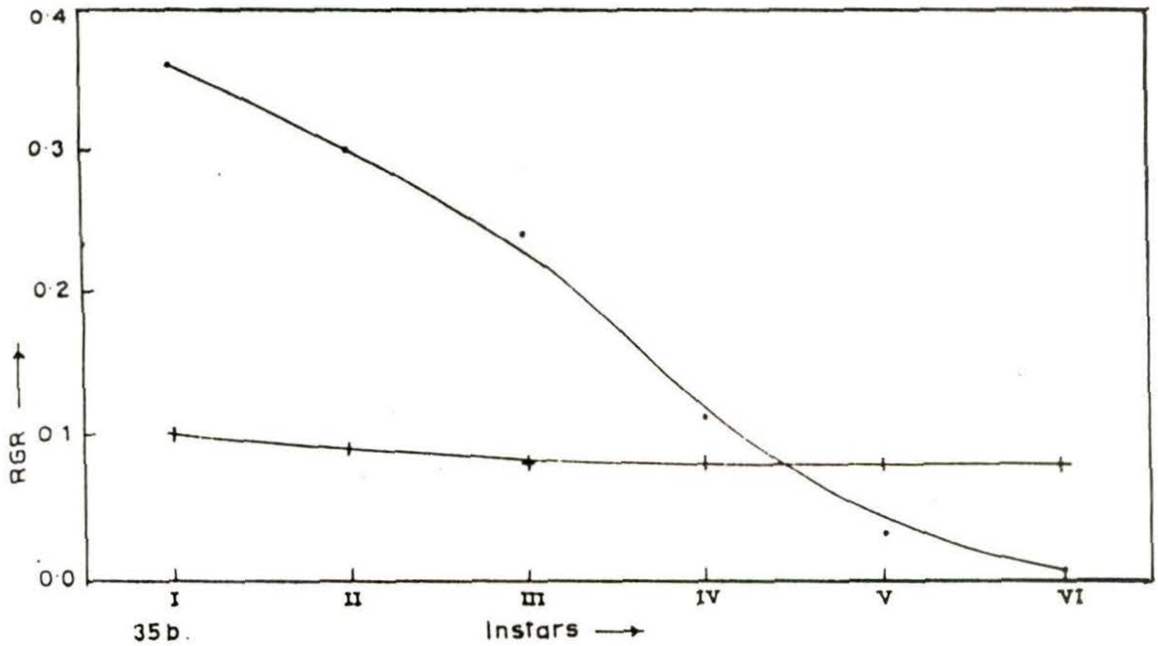


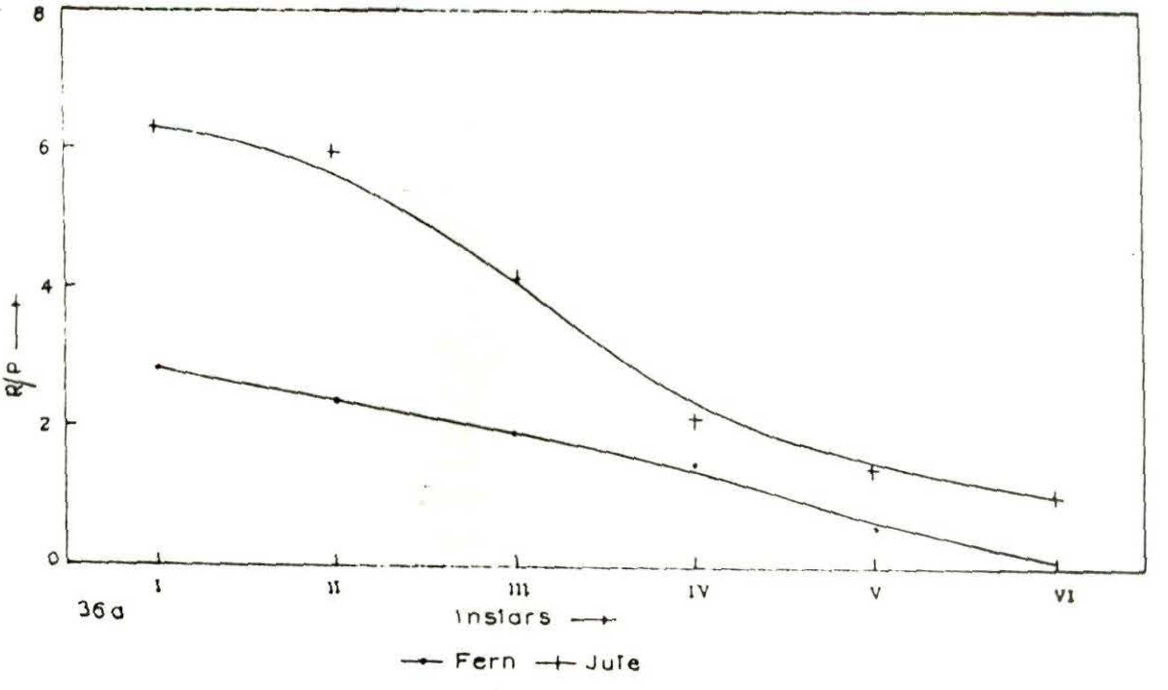
FIG. 35a.



35b.

Fig. 35a. Relative consumption rate of different nymphal stages of A. crenulata on C. crinipes and C. capsularis.

Fig. 35b. Relative growth rate of different nymphal stages of A. crenulata on C. crinipes and C. capsularis.



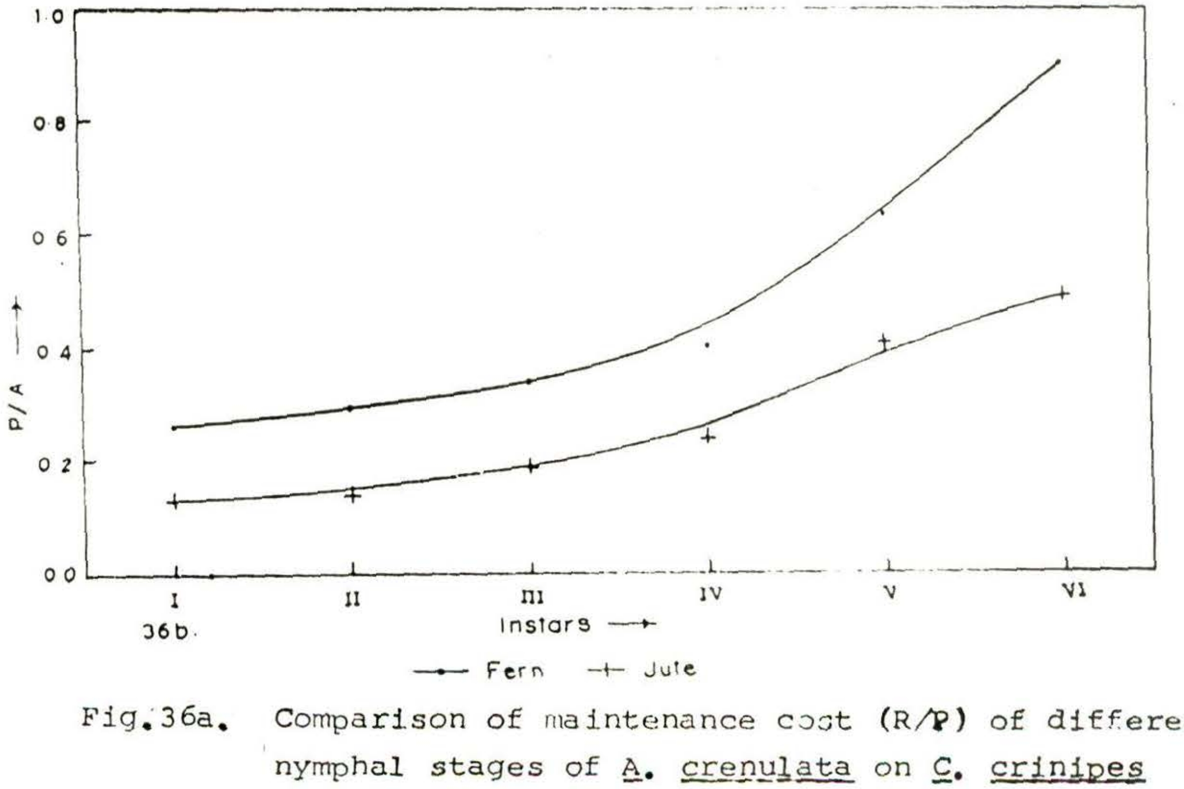


Fig. 36a. Comparison of maintenance cost (R/P) of different nymphal stages of <u>A. crenulata</u> on <u>C. crinipes</u> and <u>C. capsularis</u>.

Fig. 36b. Comparison of production index (P/A) of different nymphal stages of <u>A. crenulata</u> on <u>C. crinipes</u> and <u>C. capsularis</u>.

Table XVI a : Performance of *A. crenulata* on ferm (*C. crinipes*) and angiosperm (*C. capsularis*) hosts (mean ± SD)

Host Plant	Adult dry weight (mg)		Longevity (days)		Fecundity
	Male	Female	Male	Female	
Christella crinipes	43.40 ± 1.36	149.20 ± 1.48	31.33 ± 2.86	36.61 ± 1.01	78.20 ± 7.02
Corchorus capsularis	40.09 ± 0.34	142.95 ± 1.30	26.66 ± 4.18	33.36 ± 2.55	36.00 ± 5.78

Table XVI b. Duration (days) and survival (%) of different stages of *A. crenulata* on fern (*C. crinipes*) and angiosperm host (*C. capsularis*) (Mean ± SD)

Stage	P-Period (Days) S- Survival (%)	HOST PLANT	
		C. crinipes	*C. capsularis*
Nymphs	P.	1 - 28	1 - 32
(I-V)	S	21.41 ± 1.18	15.59 ± 1.35
Nymphs	P	29 - 38	33 - 43
VI instar ♀	S	10.70 ± 0.59	7.81 ± 0.67
Eggs	P	0 - 30	0 - 34
	S*	67.35 ± 1.48	44.01 ± 1.76

* stands for egg hatchability

Table XVII a : Survivorship table for the nymphs of *A. crenulata* on *C. crinipes*

x	n_x	l_x	L_x	T_x	e_x	q_x
0	100	1.000	95.5	783.0	7.83	0
2	91	.910	86.5	687.5	7.55	.09
4	82	.820	80.5	601.0	7.33	.10
6	79	.790	78.0	520.5	6.59	.03
8	77	.770	70.5	442.5	5.75	.02
10	64	.640	63.0	372.0	5.81	.20
12	62	.620	55.0	309.0	4.98	.03
14	48	.480	43.5	254.0	5.29	.29
16	39	.390	37.0	210.5	5.39	.23
18	35	.350	33.5	173.5	4.96	.11
20	32	.320	30.0	140.0	4.38	.09
22	28	.280	26.5	110.0	3.93	.14
24	25	.250	22.5	83.5	3.34	.12
26	20	.200	17.0	61.0	3.05	.25
28	14	.140	14.0	44.0	3.14	.42
30	14	.140	13.5	30.0	2.14	00
32	13	.130	11.5	16.5	1.27	.07
34	10	.100	5.0	5.0	0.5	.30
36	-	-	-	-	-	-

x = age in days

n_x = observed number of nymphs surviving at start of age interval x

l_x = proportion surviving at start of age interval

L_x = number of individuals alive on the average during the age interval

T_x = individuals x time units

e_x = mean expectation of further life for nymphs at start of age x

q_x = rate of mortality

Table XVII b : Survivorship table for the nymphs of

A. crenulata on *C. capsularis*

x	n_x	l_x	L_x	T_x	e_x	q_x
0	100	1.00	148.0	971.0	9.71	0
2	96	.96	93.5	823.0	8.57	.04
4	91	.91	88.0	729.5	8.02	.05
6	85	.85	82.0	641.5	7.55	.07
8	79	.79	75.5	559.5	7.08	.07
10	72	.72	72.0	484.0	6.72	.09
12	72	.72	69.5	412.0	5.72	0.00
14	67	.67	63.5	342.5	5.11	.07
16	60	.60	56.5	279.0	4.65	.11
18	53	.53	50.0	222.5	4.20	.13
20	47	.47	42.5	172.5	3.67	.12
22	38	.38	32.0	130.0	3.42	.23
24	26	.26	23.5	98.0	3.77	.46
26	21	.21	19.0	74.5	3.55	.23
28	17	.17	15.5	55.5	3.26	.23
30	14	.14	13.5	40.0	2.86	.21
32	13	.13	12.0	26.5	2.04	.07
34	11	.11	10.0	14.5	1.32	.18
36	9	.09	4.50	4.5	0.50	.22
38	-	--	--	--	--	--

x = age in days

n_x = observed number of nymphs surviving at start of age interval x

l_x = proportion surviving at start of age interval

L_x = number of individuals alive on the average during the age interval

T_x = individuals X time units

e_x = mean expectation of further life for nymphs at start of age x

q_x = rate of mortality

Table XVIII a : Stadial duration, consumption (C), egestion (Fu), assimilation (As), production (P) and respiration (R) of A. crenulata on fern (C. crinipes) and jute (C. capsularis) hosts

Host plant	Stadial period	Instar	C	Fu	As	P	R
Jute	6	I	20.70	5.29	15.41	2.11	13.30
Fern	7	"	7.75	2.96	4.29	1.12	3.17
Jute	6	II	29.31	7.31	21.79	3.14	18.65
Fern	7	"	19.88	9.29	10.59	3.15	7.44
Jute	8	III	57.56	23.74	33.82	6.57	27.25
Fern	7	"	38.02	19.20	18.82	6.43	12.39
Jute	8	IV	84.32	37.32	47.00	11.29	35.71
Fern	9	"	58.03	33.02	25.61	10.13	14.88
Jute	10	V	118.68	57.93	60.75	25.19	35.56
Fern	12	"	143.93	102.42	41.51	26.26	15.25
Jute	10	VI	229.55	162.97	136.58	68.02	68.56
fern	12	"	250.57	188.06	62.51	56.67	5.84
TOTAL							
Jute	48		540.12	294.56	315.35	116.32	199.03
Fern	54		518.18	354.95	163.33	103.76	58.97

Table XVIII b : Relative nutritional indices and efficiencies of *A. crenulata* on fern (*C. crinipes*) and jute (*C. capsularis*)hosts

Host plant	Instar	Ase	Pe_1	Pe_2	RCR	RGR	P/A	R/P
Jute	I	74.44	10.19	13.69	1.05	.10	.13	6.30
Fern	"	59.17	15.44	26.10	.83	.36	.26	2.83
Jute	II	74.34	10.71	14.41	.86	.09	.14	5.93
Fern	"	53.26	15.84	29.74	.82	.30	.29	2.36
Jute	III	58.75	11.41	19.42	.71	.08	.19	4.14
Fern	"	49.50	16.91	34.16	.74	.24	.34	1.92
Jute	IV	55.74	13.38	24.02	.65	.08	.24	2.12
Fern	"	49.72	17.45	40.50	.43	.11	.40	1.46
Jute	V	51.18	21.22	41.46	.40	.08	.41	1.41
Fern	"	28.84	18.24	63.26	.36	.03	.63	.58
Jute	VI*	45.59	22.70	49.80	.39	.08	.49	1.00
Fern	"	24.94	22.61	90.65	.28	.01	.90	0.10

* ♀ nymphs only,

Ase = Assimilation efficiency

Pe_1 = Gross production effficiency

Pe_2 = Net production efficiency

RCR = Relative consumption rate

RGR = Relative growth rate

R/P = Maintenance cost

P/A = production index

efficiency (Pe_1) was higher on mulberry but in the additional instar (VII) it was the least. With advancement of larval instars the net production efficiency (Pe_2) also showed a similar trend in increase on both the hosts. However, the values showed a sharp fall in the VIth and the additional VIIth instar on mulberry (Table XIVb). The production index (P/A) was found to be consistently higher on mulberry than D. esculentum (Fig. 28b).

C. Atractomorpha crenulata (Acrididae : Orthoptera)

i. Host plant preference

Food finding and host plant preference experiments of A. crenulata using five fern species showed a preference for two of the species, C. crinipes and D. esculentum. The nymphs showed a higher leaf area consumption of C. crinipes than D. esculentum. Adults showed a balanced choice between the above fern species (Table XVa Fig. 29a, b, c, d). Although an increase in leaf area consumption was noted in both the ferns by advanced nymphal stages, it got reduced in adults. The preference data between the fern species, C. crinipes and the angiosperm host, C. capsularis indicated a higher preference for the fern species by all stages (Table XVb) (Fig. 30 a, b).

ii. Development and performance

Development of *A. crenulata* on *C. crinipes* (fern) and *C. capsularis* (jute) showed that the average total nymphal period on *C. capsularis* was more than that on *C. crinipes* (Table XVI b) (Fig. 32a,b,c). On both the host plants the acridid species had an additional (VI) instar for the females only. Survival (%) on *C. crinipes* was higher than that on *C. capsularis*. *A. crenulata* laid almost two folds egg on *C. crinipes* than on *C. capsularis* (Fig.31). Eggs took about a month to hatch and the incubation period was slightly higher on *C. capsularis*. On *C. crinipes* % of egg survival was higher to that on jute. Both male and female longevities were found to be slightly higher on *C. crinipes* than on *C. capsularis* (Table XVI a). The average dry weights of males and females also indicated a marginally higher value on *C. crinipes*. The body weight of females on both the host plants by far exceeded those of males (Fig.33).

iii. Survivorship study

Survivorship curves of *A. crenulata* on *C. crinipes* and *C. capsularis*, showed a variation, both in number of deaths and also in the death rate (Fig.34a,b).

No fixed pattern of death rate by the nymphs were evident excepting that the death rate touched zero on C. crinipes on the 30th day while on C. capsularis, as early as on 12th day. The n_x and l_x values, however, showed a close similarity at the end of nymphal period indicating that a similar number of nymphs survived to become adults (Table XVII a,b).

A comparision of the survivorship curves of the acridid nymphs on both the hosts showed close similarities in their basic pattern. The curves stood between type I and type II, being more close to type II of the hypothetical curves (Pearl, 1928) (Fig. 6.)

iv. Dry weight nutrient (mass) budget of nymphs on fern and jute.

a. Consumption, egestion and weight gain

The nymphs of A. crenulata showed a considerable difference in the values for consumption and egestion which increased along with the advancement of instars (Table XVIII a). Production (P), however, showed a close trend of increase in the earlier instars. Only the VI instar stage, comprising the female nymphs, showed a substantial increase in weight on C. capsularis compared to that on C. crinipes. A comparision of RCR values indicated a decreasing trend in subsequent instars on both the hosts. These values on the two hosts showed a narrow difference and overlapped at times (Fig. 35a). The RGR values also showed a decrease in subsequent instars on fern which is the least in the VI instar (Fig. 35b). However, on jute the values did not differ much and became constant in the last four instars.

b. Assimilation and respiration

The assimilation values in all the nymphal instars were much higher on jute than that on fern. In general, the respiratory values also increased steadily from I-V instar on both the hosts excepting in the VI instar on fern (Table XVIII a). The cost of maintenance (R/P) of the early instars was higher than the advanced ones on both the hosts. However, it was noteworthy that the maintenance cost on jute for all instars was higher than that on fern (Fig. 36a).

c. Efficiency values

The efficiency of assimilation (Ase) was much higher on jute. However, the gross production efficiency (Pe_1)

Table XIX a : Chemical analysis and comparision of basic nutritional components (mg/g)

Food Plant	Total Dietary Protein	Total Nutritive Carbohydrate	Total Lipid	Carbohydrate Protein Ratio
Diplazium esculentum	184.31	223.64	23.03	1.21
Christella crinipes	191.55	220.75	36.52	1.15
Lindsea ensifolia	113.95	228.22	64.10	2.00
Microlepia speluncae	75.74	190.48	21.80	2.51
Dicranopteris linearis	190.19	144.72	7.75	0.76
Corchorus capsularis	178.55	564.55	22.02	3.16
Morus indica	152.58	273.63	17.84	1.79

Fern and angiosperm Hosts	TANNIN Soluble (TAE)	TANNIN Condensed	Total Phenol	Water	Fibre	Water Phenol Ratio
Diplazium esculentum	0.27	3.50	0.69	81.30	50.47	.008
Christella crinipes	0.34	3.73	0.74	72.13	54.43	.010
Lindsea ensifolia	1.45	7.51	0.81	71.84	56.07	.011
Microlepia speluncae	0.64	9.07	0.18	79.86	50.12	.002
Dicranopteris linearis	1.32	16.19	0.66	57.83	44.39	.011
Corchorus capsularis	0.26	3.97	0.94	73.27	75.25	.010
Morus indica	0.28	4.02	0.53	71.96	77.66	.006

was more on fern for the first four instars which subsequently levelled off with jute. The net production efficiency (Pe_2) clearly showed higher values on fern than that on jute (Table XVIIIb). The production index (P/A) was higher on fern as compared to that on jute, which reached the maximum value in the ultimate instar (Fig. 36b).

III. BIOCHEMICAL STUDY (DIETARY COMPONENTS) OF JUTE, MULBERRY AND FERNS

The biochemical profile in reference to basic nutrients and some non-nutritional components indicated a wide variation among the species of ferns. *Diplazium esculentum*, with a high protein and a moderate carbohydrate and lipid content appeared dietarily rich. Its carbohydrate-protein ratio was reasonably narrow. While with highest water content, this species showed a narrow phenol water ratio. Both soluble as well as condensed tannin in the species were minimum indicating low host defence.

Christella crinipes showed the highest protein content with a moderate carbohydrate and a narrow carbohydrate-protein ratio-which is close to *D. esculentum*. Lipid, fibre and phenol content were moderate. Water % was reasonably high with a moderate phenol-water ratio. Both soluble and condensed tannins were found to be slightly higher than that on D. esculentum but comparatively less than the rest of the fern species. Amongst the rest of the fern species, two of them i.e. Lindsea ensifolia and Microlepia speluncea showed a very high carbohydrate-protein ratio and lipid content. Their condensed tannin content were reasonably higher (almost two to three times) than that of D. esculentum. On C. crinipes, however, their lipid, phenol soluble tannin levels and phenol-water ratio showed great variation. In both species water content was reasonably high and their fibre contents were moderate.

The last of the fern species i.e. Dicranopteris linearis, showed narrowest carbohydrate-protein ratio but had a very low lipid content. The percentage of water content was lowest and the phenol-water ratio was moderate. Although its fibre content was the least, its condensed tannin was the highest and the soluble tannin was reasonably high.

The analysis of the economic host plant C. capsularis showed a moderate dietary protein but a very high carbohydrate content. The lipid was reasonably high and more or less in the tune of D. esculentum. Both phenol and water content were moderately high with a reasonable phenol-water ratio similar to a number of fern species. The fibre content was second highest but the soluble and the condensed tannins were of lowest and reasonably low values respectively.

Morus indica had lower values of protein and carbohydrate when compared to *C. capsularis*. It had a reasonably low carbohydrate-protein ratio and lipid content. The plant also had low values for phenol, soluble and condensed tannins. Despite having the second lowest phenol-water ratio, its fibre content was found to be highest and close to *C. capsularis* (Table XIX a,b).