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Parasitism of Spruce Budworm by *Glypta* and *Apanteles* at Different Crown Heights in Montana

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Introduction

Glypta fumiferanae (Vier.) (Ichneumonidae) and *Apanteles fumiferanae* Vier. (Braconidae) are two of the most common parasites of immature larvae of the spruce budworm, *Choristoneura fumiferana* (Clem.). Females parasitize the minute host larvae in the fall. Their eggs or larvae lie dormant within the hibernating host larvae, and then resume development in the spring, when the spruce budworm larva breaks hibernation and commences to feed. The budworm host is killed by *Apanteles* usually when it is in the fifth larval instar or by the *Glypta* when it is in the sixth instar.

The parasite females lay their eggs within the body of the first or second instar budworm larva, probably most commonly after it has spun its hibernaculum. Results of this study indicate this to be true, although Miller (1959) states that *Apanteles* will oviposit freely in the active, crawling larvae.

Jaynes (1954) has shown that spruce budworm larvae on balsam fir in Maine were more heavily parasitized by *Apanteles* in the upper crown of the tree. Miller (1959) came to the same conclusion in New Brunswick studies. Jaynes' figures for *Glypta* were not conclusive, probably because *Glypta* comprised only a small part of the parasite population in his study.

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Two reasons justify repeating Jaynes' experiment in Montana. First, valuable information should be obtained on *Glypta*, which is generally more abundant than *Apanteles* in the Rocky Mountains. Second, the principal western host tree is Douglas-fir, which is rough-barked in contrast to balsam fir. Therefore, an experiment was set up to determine the occurrence of these two parasites at different crown heights under local conditions.

The spruce budworm hibernates as second instar larvae, each in a small web, or hibernaculum, in various crevices on the bark of foliated and bare parts of limbs or the trunk of the host tree. Lichens, when present, are a favourite hibernating place. The thicker bark of the trunk of the tree, with its deep crevices, probably receives most of the larvae, but the trees used in this study are sampled yearly for budworm parasites, and so cannot be sacrificed by felling to remove a bole section.

A whole limb from the lower crown is a handy sampling unit, usually offering considerable rough bark for concealment of the larvae, and having further advantage that individual trees can be sampled yearly without injury. This study has not determined whether such a limb gives an example of parasitism that would be typical for the entire tree; neither does it determine at what height in the tree a limb would give a better sample.

Methods

Dominant or codominant trees ranging in height from 40 to 85 feet were selected for sampling. Limbs or stubs near the ground made climbing easier. The trees were Douglas-fir, except for one spruce (Table 1). Limbs from the 12 trees selected were cut from the lower, middle, and upper thirds of each crown. Because of differences in height of the individual trees and in the total crown length, limbs in the lower third were taken at heights ranging from 6 to 15 feet, the middle third from 16 to 35 feet, and the upper third from 28 to 60 feet (see Table 1).

There was a disparity in sample size due to the great variation in size of limbs from tree to tree and within the crowns of individual trees. The uppermost limbs were always smaller and usually smooth-barked, whereas some lower crown limbs were extremely large or rough-barked and one was nearly devoid of foliated twigs. Dead limbs were not sampled. As many as three to five limbs were cut from the upper crown of certain trees to compensate for their smaller size. Some trees were sampled twice, in an effort to obtain adequate numbers of larvae from certain heights. A record was made of the length, basal diameter, and approximate bark surface of each limb. Limbs varied from 5 to 15 feet in length and from ¾ to 3⅛ inches in diameter.

Limb samples were taken March 26, April 7, April 26, and May 18, 1958. There was evidence that hibernation was breaking on the latter date, so the larvae reared from collections on that date, including trees number 3 and 7, are not included in the comparison of larvae reared from foliated versus nonfoliated parts of the limbs (Tables III and IV).

The limb samples were brought into the laboratory, separated into foliated twigs and nonfoliated larger branches, and then placed in 5-gallon ice cream cartons according to a method devised by Denton (1953) and illustrated by Terrell (1959) for forced emergence of budworm larvae from bole sections. As the emerging larvae entered glass vials fitted into the lids of the cartons, they were removed daily and dissected under a binocular microscope to determine parasitism. If they could not be dissected immediately they were refrigerated alive until dissection.

TABLE I

Description of the trees sampled

Tree number		Plot number	Tree size		Height above ground at which limbs were removed (in feet)			Notes
serial	permanent		height (feet)	d.b.h. (in.)	lower crown	middle crown	upper crown	
1	55	3	80	26	15	35	50-55	"Wolf" tree; large limbed
2	58	3	52	12	14	32	44	
3	60	3	55	16	6	25	37-45	
4	63	3	65	16	9-14	28-35	50-52	Engelmann spruce
5	66	3	65	13	10-13	25	41-50	
6	75	3	55	14	7	22-24	37-43	
7	75a	3	40	12	7-10	20	32	
8	77	3	70	12	2-10	20-30	40-49	
9	4	1	80	18	8	20-24	40-60	Large limbs, dense crown
10	8	1	65	12	15	24	44	
11	28	2	52	12	9	24	42	Dense, full crown
12	—	—	42	12	9-10	16-20	28-32	

Each budworm larva was dissected in a droplet of water on a microscope slide or "Vapocan" lid under medium power of a binocular dissecting microscope. The egg shells of *Glypta* are often visible beneath the skin of the undissected larva, but cannot be accepted as proof of parasitism by *Glypta*, because it was frequently found that *Apanteles* had also parasitized the same larva host and invariably had overcome the *Glypta* larva or prevented the *Glypta* egg from hatching. Often two or three and even as many as six *Glypta* eggs are found within one larva, but only one parasite, be it *Glypta* or *Apanteles*, ever survives within a single host.

Identification of these two parasites was made by comparison with published figures. The life history stages of both have been described and figured by Brown (1946 a,b).

Glypta has an elongate, brown egg, which is about as long as the diameter of the second instar host larva. The first instar larva has a brown, asymmetrical thimble-shaped head capsule which is turned downward and is no wider than the diameter of the body. Rarely a dissected budworm will contain an unhatched egg, sometimes a dead egg which has darkened, and occasionally a hatched egg shell is present, with no trace of either a *Glypta* or an *Apanteles* larva. In these instances the larva is considered to be parasitized by *Glypta*.

Apanteles eggs are said by Brown (1946a) to be brown in colour, but they have never been recognized in Montana dissections. Apparently the *Apanteles* egg hatches in the fall, whereupon the empty shell completely disintegrates, or may be eaten by the parasite larva. The first instar larva is white in colour and shaped like a flatheaded borer larvae, with a broadened head. It is very hard to distinguish against a white background, and for this reason a light brown or grey background is preferred for making dissections. The living *Apanteles* larva often curls into a ball when released from its host, and sometimes will be first noticed floating in the surface film upon re-examination of the droplet.

To review super or multiple parasitism, only one parasite larva per host survives more than a short time after hatching, and *Apanteles* always kills *Glypta*

TABLE II

Emergence of hibernating spruce budworm larvae and their parasitism by *Glypta* and *Apanteles* at three crown heights in 12 trees

Tree number	No. of budworm larvae in lower crown			No. of budworm larvae in middle crown			No. of budworm larvae in upper crown			No. of budworm larvae in entire crown		
	Total	Parasitized		Total	Parasitized		Total	Parasitized		Total	Parasitized	
		by Glypta	by Apanteles		by Glypta	by Apanteles		by Glypta	by Apanteles		by Glypta	by Apanteles
1	17	3	0	144	50	10	19	2	3	180	55	13
2	35	11	7	19	6	5	7	0	0	61	17	12
3	221	107	18	90	24	25	167	37	25	478	168	68
4	172	41	5	78	22	12	75	9	7	325	72	24
5	94	37	7	133	33	12	236	59	40	463	129	59
6	60	27	2	39	10	8	24	5	4	123	42	14
7	59	22	12	92	25	25	38	12	6	189	59	43
8	46	9	0	141	43	34	34	4	8	221	56	42
9	172	24	17	503	86	25	100	12	19	775	122	61
10	89	18	6	120	25	23	40	3	9	249	46	38
11	813	192	113	602	100	81	214	51	60	1,629	343	254
12	299	98	35	260	49	84	119	22	39	678	169	158
Total	2,077	589	222	2,221	473	344	1,073	216	220	5,371	1,278	786

if, as commonly happens, they compete for the same host. The surplus *Glypta* larvae appear to vanish without a trace, whether they are killed by their own kind or by *Apanteles*. Not even an empty *Glypta* head capsule has been found in budworm larvae harbouring four to six hatched *Glypta* egg shells. The surviving larva, be it *Glypta* or *Apanteles*, does not appear to have increased in body size, nor can any aliment be distinguished in its gut.

Results

A total of 5,371 spruce budworm larvae were recovered from 12 trees, the number per tree varying from 61 to 1,629. Parasitism on an individual tree basis ranged from 23.6 (tree no. 9) to 53.9 per cent (tree no. 7), and averaged 38.4 per cent. *Glypta* outnumbered *Apanteles* in all trees studied, but by only a few individuals in some trees (Table II).

The data in Table II were tested by Wilcoxon's (1949) method for determining the significance of differences between paired replicates. For *Glypta* there is no significant difference between the lower and middle thirds of the crown but parasitism was significantly higher in the lower third and the middle third, compared with the upper third of the crown. For *Apanteles* there is no significant difference between the middle and upper thirds of the crown, but a highly significant increase in parasitism in the middle and a significant increase in the upper third, as compared with the lower third of the crown. For combined parasitism by both *Glypta* and *Apanteles* there was a significant decrease in the upper third compared with the middle third; other differences were not significant.

Calculation of parasitism by *Glypta* based on means from individual trees shows: lower third 29.5 per cent, middle third 24.9 per cent, upper third 16.2 per cent. Calculation of parasitism by *Apanteles* based on means from individual trees shows: lower third 8.6 per cent, middle third 19.2 per cent, and upper third

TABLE III

Emergence of hibernating spruce budworm larvae and their parasitism from the nonfoliated parts of limbs at three crown heights

Tree number	No. of budworm larvae in lower crown			No. of budworm larvae in middle crown			No. of budworm larvae in upper crown			No. of budworm larvae in entire crown		
	Total	Parasitized		Total	Parasitized		Total	Parasitized		Total	Parasitized	
		by Glypta	by Apanteles		by Glypta	by Apanteles		by Glypta	by Apanteles		by Glypta	by Apanteles
1	15	3	0	64	26	5	7	1	1	86	30	6
2	32	11	6	18	6	4	0	0	0	50	17	10
4	140	34	1	6	1	0	4	2	1	150	37	2
5	77	33	5	28	10	3	6	4	0	111	47	8
6	29	16	0	13	4	2	2	1	0	44	21	2
8	46	9	0	97	36	27	12	2	3	155	47	30
9	129	19	10	454	81	16	60	8	6	643	108	32
10	68	15	4	44	17	5	6	0	1	118	32	10
11	466	126	42	364	68	41	2	0	2	832	194	85
12	219	87	18	66	18	23	2	0	0	287	105	41
Total	1,221	353	86	1,154	267	126	101	18	14	2,476	638	226

17.9 per cent. Calculation of combined parasitism by *Glypta* and *Apanteles* shows: lower third 38.1 per cent, middle third 44.1 per cent, and upper third of crown 34.1 per cent.

A comparison of the emergence and parasitism of budworm larvae from the foliated portions of the limbs with those from the nonfoliated portions, or "bark," is possible from data presented in Tables III and IV. Certain data, including those pertaining to trees 3 and 7, had to be dropped from those tabulations because the last collection was made after the larvae had started to break hibernation and move to the new buds. An examination of Table III shows that very few larvae were obtained from the bark of limbs from the upper third of the crown and Table IV shows that the first six trees listed yielded relatively few larvae from the foliage at all levels.

Despite these inadequacies, it is possible to determine the significance of the differences between parasite populations recovered from the bark and those recovered from foliage. Parasitism by *Glypta* was highly significantly greater in the budworm larvae reared from the bark than in those reared from foliage. *Apanteles* parasitism was significantly greater in the foliage than in the bark. Parasitism by *Glypta* and *Apanteles* combined, however, is not significantly greater in the bark than in the foliage.

Limbs from the lower and middle thirds of the crown yielded twice as many budworm larvae from the bark of the nonfoliated parts of the limb as from the foliated twigs (Tables III and IV), whereas limbs from the upper third of the crown yielded five times as many larvae from the foliated twigs as from the relatively smooth-barked nonfoliated parts of the limbs (Table IV). For most trees, very few larvae were reared from the foliage samples taken from the low part of the crown; tree 11 is an outstanding exception.

TABLE IV

Emergence of hibernating spruce budworm larvae and their parasitism from foliated parts of limbs at three crown heights

Tree number	No. of budworm larvae in lower crown			No. of budworm larvae in middle crown			No. of budworm larvae in upper crown			No. of budworm larvae in entire crown		
	Total	Parasitized		Total	Parasitized		Total	Parasitized		Total	Parasitized	
		by Glypta	by Apanteles		by Glypta	by Apanteles		by Glypta	by Apanteles		by Glypta	by Apanteles
1	2	0	0	1	0	0	11	1	1	14	1	1
2	3	0	1	1	0	1	7	0	0	11	0	2
4	8	1	1	4	0	0	57	6	5	69	7	6
5	8	3	1	7	2	0	9	3	1	24	8	2
6	3	1	0	26	6	6	22	4	4	51	11	10
8	5	0	0	39	7	7	22	2	5	66	9	12
9	43	5	7	49	5	9	40	4	13	132	14	29
10	21	3	2	76	8	18	34	3	8	131	14	28
11	347	66	71	238	32	40	212	51	58	797	149	169
12	80	11	17	194	31	61	117	22	39	391	64	117
Total	520	90	100	635	91	142	531	96	134	1,686	277	376

Conclusions

Glypta fumiferanae exerts its highest parasitism on spruce budworm larvae hibernating in the coarse bark crevices of the lower and middle part of the crown. *Apanteles fumiferanae*, with its shorter ovipositor, most successfully parasitizes larvae in the foliage, and is most abundant in the upper and middle part of the crown. Since a large part of the budworm population on each Douglas-fir host probably hibernates in the bark crevices of the bole, a site favoured by *Glypta* and not favoured by *Apanteles*, neither larvae from bole sections nor larvae from limbs can be expected to give a true picture of parasitism. A whole limb from the middle third of the crown appears to be adequate for determining proportional parasitism by these two insects, but shows a slightly exaggerated picture of parasitism. When one considers the preponderance of *Glypta* in larvae hibernating in the bole of the tree, a fact previously established from studies of bole sections though boles were not sampled in this study, one must admit that a limb from a lower crown position may give the best index of parasitism. Perhaps this limb should be from the lowermost whorl of vigorous branches. This should be confirmed by determining the distribution and parasitism of the spruce budworm on an entire tree basis.

Summary

Limbs were obtained from lower, middle, and upper thirds of the crowns of 12 trees, predominantly Douglas-fir, infested with spruce budworm, *Choristoneura fumiferana* (Clem.). Issuing budworm larvae, varying in number from 61 to 1,629 per tree, were dissected to determine the amount and distribution of parasitism by the larval parasites *Glypta fumiferanae* (Vier.) and *Apanteles fumiferanae* Vier. Parasitism from both species varied from 23.6 per cent to 53.9 per cent per tree, with an average of 38.4 per cent. Parasitism by *Glypta* was significantly higher in the lower and middle crowns than in the upper crown and that by *Apanteles* was significantly greater in the upper and middle crowns as

compared with the lower crown. Combined parasitism was greatest in limbs from midcrowns. A comparison of rearings from foliated and nonfoliated parts of the limbs clearly showed that *Glypta* is more abundant in budworm larvae hibernating under bark scales, whereas *Apanteles* is most common in larvae hibernating in the foliage. In this experiment, parasitism of budworm larvae averaged 23.8 per cent from *Glypta* and 14.6 per cent from *Apanteles*.

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Artificially Disseminated Virus as a Factor Controlling the European Spruce Sawfly, *Diprion hercyniae* (Htg.) in the Absence of Introduced Parasites[1]

By F. T. Bird and J. M. Burk

An outbreak of the European spruce sawfly, *Diprion hercyniae* (Htg.), occurring in Eastern Canada between 1930 and 1942, was controlled by a virus disease (Balch and Bird, 1944). The sawfly has been kept at a low level by the disease and by parasitic insects introduced from Europe (Bird and Elgee, 1957).

An infestation of the sawfly was discovered in 1947 near Sault Ste. Marie, Ontario, by the Forest Insect Survey Section of the Forest Biology Laboratory at Sault Ste. Marie. This infestation was about 100 miles beyond the previously known western distribution of the insect. Intensive larval sampling in 1949 showed that it was free from virus and practically free from introduced parasites.[2] Thus, an excellent opportunity was provided to introduce the virus into a disease-free population, to study its establishment and spread, and to compare the long term effects of virus alone on population trends with the effects that virus plus introduced parasites were shown to have on population trends in New Brunswick

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[2]*Drino bohemica* Mesnil was liberated in the area in 1948, and a few specimens were recovered near the liberation points in 1949 (Annual Report of the Forest Insect Survey 1949, p. 56).