LABORATORY BIOLOGY OF THE DUSKY SAP BEETLE[1] AND FIELD INTERACTION WITH THE CORN EARWORM[2] IN EARS OF SWEET CORN[3]

GEORGE TAMAKI[4], LEE FOX[5] AND PAUL FEATHERSTON[5,6]
Yakima Agricultural Research Laboratory,
Agricultural Research Service, USDA,
Yakima, WA 98902

ABSTRACT

The developmental rates of the egg, larval and pupal stages of the dusky sap beetle, *Carpophilus lugubris* Murray, reared on artificial diet at 21 °C were 4.04, 22.27, and 9.2 days, respectively, a total of 35.5 days. The mean lifetime of adult females was 263 days, or about 110 days longer than previously reported. Its population growth statistics were as follows: intrinsic rate of increase = 0.340 ♀/♀/week, generation time 12.20 weeks, and net reproductive rate = 63.1 ♀/♀/week. Field studies established that the sap beetles can successfully invade ears of corn throughout the season in the absence of corn earworms, *Heliothis zea* (Boddie). However, more sap beetles were found in ears infested with corn earworm than in ears not so infested. Eggs of *Geocoris* sp. were more abundant in infested ears with corn earworms and sap beetles than in uninfested ears; however, adults of *Orius tristicolor* (white) did not display such a preference.

In recent years, the dusky sap beetle, *Carpophilus lugubris* Murray, which has been reported as a major pest of sweet corn in Utah (Knowlton 1942), Maryland (Lee et al. 1953), Delaware (Connell 1956), and Illinois (Yero 1957), has become a pest of sweet corn in the Yakima Valley of Washington.

This paper describes research in areas not so far emphasized in the intensive biological and ecological studies of the dusky sap beetle conducted by Connell (1956), Harrison (1962), and Sanford (1963). The data contribute to the construction of a life table for population growth statistics. We also made field studies to determine the ecology of the dusky sap beetle, the corn earworm, *Heliothis zea* (Boddie), and populations of two natural enemies of the larvae of these pests found in ears of sweet corn in Washington.

MATERIALS AND METHODS

Life Table

The life table of the dusky sap beetle was constructed by rearing adult beetles from 75 eggs. The adult biology was studied by following 100 newly emerged adults until they died. The rearing procedures for the larval and adult studies were as follows:

The rearing chamber for the individual larvae were small plastic jelly cups (vol 13 ml) that had the bottom layered with 3 ml of a 2% agar solution and the top covered with a snap-on plastic lid. After a newly deposited egg was placed on the agar, it was observed for hatching, when a small piece of artificial diet was added as food for the larva. The diet used was modified from the artificial diet for the alfalfa looper, *Autographa californica*, and the celery looper, *Syngrapha falcifera*, reported by Treat and Halfhill (1973), in that we substituted 300 g of cornmeal for alfalfa leaf meal. A sheet of plastic the same size as the piece of diet was placed between the diet and the agar to prevent contact between the two media. As the larvae grew, larger cubes of diet were added. The cages were checked daily and cleaned, fresh food was added, and changes in larval instar based on exuviae were recorded.

The adult dusky sap beetles were reared by placing 100 pairs of newly emerged males and females in individual plastic jelly cups of the type used to rear the larvae. Moist blotter paper instead of agar was put on the bottom of the rearing cup to supply moisture and as an oviposition site. A cube of the same artificual diet used for larvae, was placed on the blotter paper. The cages were checked 5 days a week, and all eggs were removed. Both larvae and adult beetles were held in a temperature controlled room (21 ± 1.5°C) with a 16-h photophase.

Field studies

In the 1st field study, we examined the interaction of the dusky sap beetle with the corn earworm, and both with the possibly related abundance of adults of the minute pirate bug, *Orius tristicolor* (White), and eggs of the big-eyed bug, *Geocoris* spp., laid on the corn silk, in two varieties of sweet corn. These predaors attack both eggs and larvae of the corn earworm and sap beetles. Each week for 10 consecutive weeks (Apr. 11 to June 13, 1978), one

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[3]Received for publication 27 August 1981.
[4]Research leader and research entomologist.
[5]Biological Technician.
[6]Retired, January, 1980.

plot (30 m long), of the corn variety, Morning sun (Northrup King 36987), considered medium to tight husk, and one plot (30 m long) of the variety, Reliance (NK 36828), considered medium to loose husk, were planted at laboratory field plots. Plots of the two varieties were alternated along a single 120 m row. Thus, each week, 20 ears of corn of each variety from each of 2-5 different-aged corn plots could be harvested and sampled. The weight of the ears, whether the exposed silk was white or brown, the presence of insects, and evidence of beetles by frass or feeding damage were determined for each ear. All data were recorded on a disk for computer compilation and analysis.

The 2nd field test was made to determine whether the dusky sap beetles were overwintering at the infested site of the 1st field test. The test area was therefore a field planted in early summer 1978 and not harvested; it had received no chemical treatment during the summer when earworn and sap beetle populations were high. We took 30 to 50-cm^2 + soil samples to a total depth of 25 cm and examined each 5 internal for overwintering pupae of the sap beetle and the corn earworm.

RESULTS AND DISCUSSION

Biology and Population parameters

The survival and development rates for all life stages of dusky sap beetles held at 21C are reported in Table 1. The time for development of the larval stages totalled 22.27 days and 35.5 days was required to complete all immature stages. The sexes did not differ in the time required to reach adulthood.

In Figure 1, the survivalship curve at the time of eclosion at 21°C, and 5 weeks, started at 87%. Reproduction began in the 5th week, the maximum number of eggs was oviposited during the 7th week (the number that would produce females, 4.97, was based on a sex ratio of 1:1), and reproduction continued until the last female died, at 61 weeks, (Fig. 1).

Our data therefore differ in some degree from those reported by others. Sanford (1963) reported a 129.6-day mean adult life for the female at 23.9°C (on a dried apricot diet); and Connell (1956) reported a 150-day mean adult life with the same temperature and diet. In our study, the average mean adult of females from egg deposition to death was 263 days ± 6.7 SE (range 7-427 days), which is considerably longer. Foott and Timmins (1979) reported the mean longevity of adult females of the nitidulid *Glischrochilus quadrisignatus* (Say), to be 137 days (range 44-239 days).

The data for survival rates and fecundity rates presented in Fig. 1 were used to calculate the population growth statistics reported in Table 2. The intrinsic rate of increase of the dusky sap beetle (0.340 ♀/♀/week) is the biological characteristic that describes a population increasing in an environment unlimited in food and space. The antilog of r_m is the finite rate of increase, thus a population of 100 beetles at week-1 will increase to 140 in week-2. The population will double itself in 2.04 weeks. The generation time is 12.2 weeks which is the mean time elapsing between the birth of the parents and the birth of the offspring. The gross reproductive rate m_x is 89.6 or the average number

TABLE I. Percentage survival and duration of immature life stages of the dusky sap beetle held on artificial diet at 21°C (starting with 75 eggs).

Life stage	% survival	Duration of stage (days $\bar{X}$ ± SE)
Eggs	100	4.04 ± .07
Instar 1	100	4.56 ± .12
Instar 2	100	4.52 ± .10
Instar 3	100	3.53 ± .11
Instar 4	97	9.66 ± .24
Pupae	87	9.20 ± .12

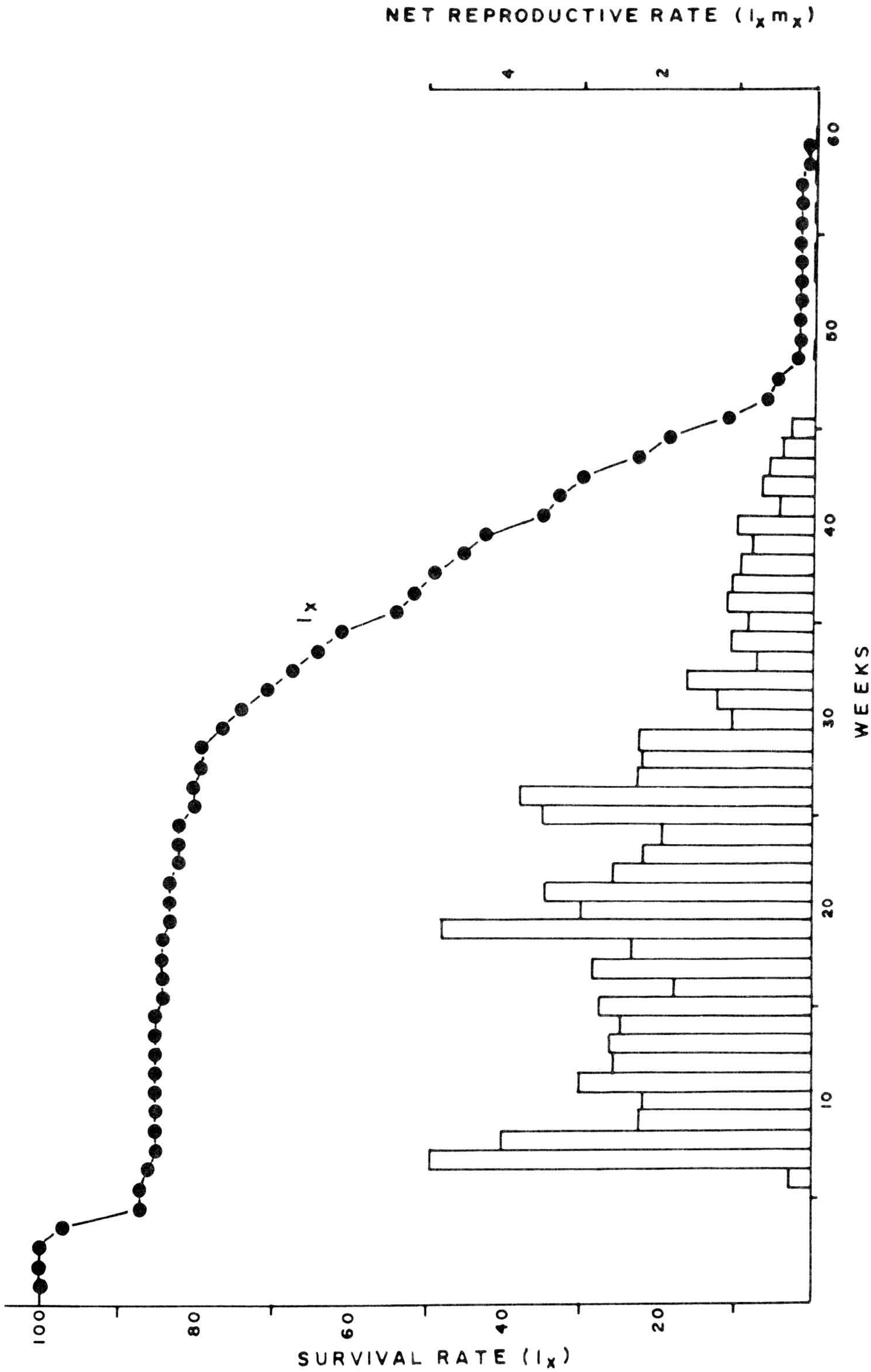

Figure 1. Survivorship curve and net reproductive rate of the dusky sap beetle.

of female eggs laid per female each week, and the net reproduction of R_0 of 63.1 is the number of eggs that will produce females laid by an average female in a generation.

Field Studies

The 50 soil sample taken in March 1979 in the undisturbed corn field resulted in 11 sap beetle pupae and 16 corn earworm pupae at soil depths as shown:

Depth cm	Sap beetle pupae	Earworm pupae
5	4	3
10	5	9
15	2	4

About half the pupae were between 5-10 cm. No pupae were found below 15 cm. In the test during the growing season, there were no significant differences in abundance of the three types of insects and number of ears with silk for the different ages of plants and two varieties. Therefore, data on planting dates and varieties were pooled and reanalyzed.

Seasonal activity of the two pest species (Table 2) was determined from the weekly samples of corn ears. The 1st sample, taken July 11, 1978, showed that eggs and adults of the dusky sap beetle beetle were the principal life stages present; by July 24, all life stages were present and in nearly equal numbers. The greatest numberof adult beetles was present in late July and August, with the peak population about Aug. 7. However, the peak of oviposition of the corn earworm moths on sweet corn was about Aug. 1, and the greatest number of earworms was present from mid-to late-August.

Our data on the interaction between the dusky sap beetle and the corn earworm are presented in Table 3. The dusky sap beetle was clearly capable of invading ears of undamaged corn throughout the season. On July 24 and Aug. 7, which were the sampling periods with the greatest number of sap beetles inside the ears, there were significantly more in ears with corn earworms than in clean ears.

Geocoris eggs were most abundant Aug. 1, which was when the peak population of the 2nd generation of *Geocoris pallens* Stal was present (Tamaki and Weeks 1972). The egg laying preference of this predator on the silk outside the ear proved to be corn ears infested with either or both eggs and larvae of the corn earworm and the dusky sap beetle (Table 3). The minute pirate bug was most abundant around July 18; thereafter, the numbers decreased (Table 2) and the predator did not display any significant preference for corn ears with corn earworm on sap beetles.

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TABLE 2. Seasonal trends in field populations of dusky sap beetle, corn earworm, and natural enemies in ears of sweet corn in Central Washington.

	No. /100 ears								
	Dusky sap beetle				Corn earworm			Geocoris	Orius
Date	Eggs	Larvae	Adults	Total	Eggs	Larvae	Total	Eggs	Adults
July 11	23	1	16	40	1	31	32	0	0
18	0	0	30	30	1	19	20	0	78
24	196	135	147	478	0	70	70	0	32
Aug 1	24	28	24	76	113	26	139	68	33
7	48	1833	173	2054	4	19	14	6	16
14	23	123	100	246	32	239	271	7	13
21	89	508	211	808	12	200	212	1	9
29	168	654	151	973	3	218	221	0	0

TABLE 3. Frequency of dusky sap beetles in ears with or without corn earworms and frequency of **Geocoris** eggs, in ears with or without corn earworms or sap beetles[a/] in Central Washington.

Table 3.--Frequency of dusky sap **beetles** in ears with or without corn earworms and frequency of Geocoris eggs, in ears with or without corn earworms or sap beetles[a/], in Central Washington.

	Mean no. of dusky sap beetle/ear[c/]		Mean no. of Geocoris eggs/ear[c/]	
Date	Ears with corn earworms	Ears without corn earworms	Ears with corn earworms or sap beetles	Ears without corn earworms or sap beetles
July 11	0.198 a	0.485 a	0.0 a	0.0 a
18	.570 a	.253 a	.0 a	.0 a
24	6.550 a	1.448 b	.0 a	.0 a
Aug. 1	2.628 a	.080 a	.540 a	.363 b
7	24.270 a	9.610 b	.055 a	.055 a
14	2.365 a	.390 a	.078 a	.0 b
21	b/ c/	b/	b/	b/
29	b/	b/	b/	b/
$\Sigma\bar{x}$	6.097 a	2.045 b	.112 a	.070 b

a/ All stages of sap beetle inside corn husk.

b/ All inspected ears had corn earworm, therefore, no comparison available.

c/ Analysis of variance with Duncan's multiple range test, all paired means with different letters were significantly different at the 5% level of confidence.

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MORTALITY OF SPRUCE BEETLE BROODS IN BOLTS SUBMERGED IN WATER

L. SAFRANYIK AND D. A. LINTON

Environment Canada
Canadian Forestry Service
Pacific Forest Research Centre
506 West Burnside Road
Victoria, B.C. V8Z 1M5

ABSTRACT

Six weeks of continuous submersion in water of spruce bolts containing larvae and young adults of the spruce beetle resulted in complete mortality. We estimated that 22 days of continuous submersion would be required to kill 50% of the brood. Brood development ceased in the submerged bolts even though water temperature, which increased from 13.3°C to 17.8°Cduring the experiments, was well above the larval development threshold (6.1 C).

RESUME

Après six semaines d'immersion complete dans ;'eau, les larves et les jeunes adultes du dendroctone de l'épinette qui infestent des billes d'épinette sont completèment dués. Nous avons estimé que 22 jours d'immersion teuraient la moitié des dendroctones. Dans les billes immergeés, la croissance des dendroctones a cessé même si la temperature de l'eau qui est passée de 13,3°C a 17,8°C, au cours de l'expérience, était bien au-dessus du seuil propice au développement larvaire (6,1°C).

INTRODUCTION

The spruce beetle, *Dendroctonus rufipennis* (Kirby) (Coleoptera: Scolytidae), is one of the most destructive insect pests of mature spruce *(Picea* spp.) in North America (Schmid and Frye 1977). In British Columbia, this bark beetle causes widespread killing of white and Engelmann spruce during periodic outbreaks.

Logging of currently infested trees combined with processing of the logs before emergence of the beetles and treatment of the bark and slabs are common practices for reducing further damage. At mill sites or log storage areas, the infested logs represent a hazard to surrounding spruce stands, from early May to late June, when the new generation of beetles emerges and flies to attack new host material such as live trees, logging residue, or wind-felled trees. When infested logs cannot be used before the beetles fly, alternative treatments are needed to destroy the beetles. For example, infested logs could be debarked and the bark buried or burned, or they could be treated with bark penetrating insecticides; however, these treatments are expensive and the latter may be environmentally undesirable.

Water sprinkling has been used effectively for reducing emergence of the mountain pine beetle, *D. ponderosae* Hopk. from decked lodgepole pine (McMullen and Betts 1982). Miller and Keen (1960) reported that ponderosa pine bark infested by broods of the western pine beetle, *D. brevicomis* Lec., submerged in water at constant 21°C. required 5 weeks of treatment to bring about 100% mortality. This report describes the mortality and development of spruce beetle broods (larvae and young adults) in bolts submerged in water for various periods.

MATERIALS AND METHODS

On April 29, 1981, five logs were cut from two infested, wind-felled spruce *(P. glauca* Moench — *P. engelmannii* Parry hybrid population) on the Naver Forest, about 65 km southeast of Prince George, British Columbia. The windfall became infested during the spring of 1980 and contained mature larvae, pupae and some brood adults.