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ECOLOGICAL STUDIES ON THE GOLDENROD GALL FLY, *EUROSTA SOLIDAGINIS* (FITCH) (DIPTERA : TEPHRITIDAE) *

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INTRODUCTION

The goldenrod (*Solidago* sp.) is a weed which entered Japan from North America (Fukuda, 1971). It has already extended throughout Japan(Fukuda, 1982; Nakagawa and Enomoto, 1975). The outbreak of this weed has made its control necessary (Takafuji, 1978).

Many investigators have tried to control accidentally introduced weeds by using insects and reported successful biological control of weeds (Andres and Goeden, 1969; Andres et al., 1973; Holloway, 1964; Huffacker, 1964). Although in Japan a few insects parasitize goldenrod, they scarcely have hindered the reproduction of the goldenrod (Takafuji, 1978). The goldenrod gall fly, *Eurosta solidaginis* is widely distributed in North America and forms ball gall(s)on the stem of the goldenrod(Rhodes, 1974; Uhler, 1961). Naito (1973) looking for natural enemies to the weeds in North America has suggested that *E. solidaginis* could be a promising natural enemy to the goldenrod. However, this insect has never been found in Japan. The biology and ecology of *E. solidaginis* must be investigated in the original place before introduction of this insect into Japan for the control of the goldenrod.

Basic aspects of the biology and ecology of the fly were studied in fields located in the southwestern United States. Furthermore, the possibility of partial control of the goldenrod by the fly was discussed.

METHODS

Observation area

Experiments on the biology and ecology of the goldenrod gall fly, *E. solidaginis* were conducted along the coastal Texas plane from September 1983 to July 1984. Samples of ball galls randomly collected were brought into the laboratory and opened to observe the fly larva and its parasites.

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RESULTS AND DISCUSSION

Morphology

Since the goldenrod gall fly, *E. solidaginis* has never been found in Japan, the morphology of the fly is described first.

Adult: The adult is dark brown to black. The wings are reticulated with a conspicuous hyline indentation which presents on the margin of cell $2dM_2$ (Plate 1). Sex is easily differentiated; the female having a short ovipositor at the apex of the abdomen, whereas the abdomen of the male is bluntly rounded. The adult length as the distance from the base of the antennae to the apex of the abdomen was 6 to 7 mm.

Egg: Eggs were not collected. According to the observations by Uhler (1951), the egg is fusiform in shape with the widest portion in the center and glistening white. The average length is said to be 0.9 mm.

Larva: The full grown third instar larva is barrel-shaped, tapering abruptly at the posterior end. The color of the larval body except for the mouth hook is milk-white. The hibernating larvae grew rapidly in September through October or November and they were heaviest in December followed by a decrease in January (Table 1). The decreased weights in January coincided with the desiccation of the ball galls after the host plants senesced(November through December). Although the length of the full grown larvae was about 7 mm, some were smaller.

TABLE 1 Changing weight of *E. solidaginis* larvae during hibernation

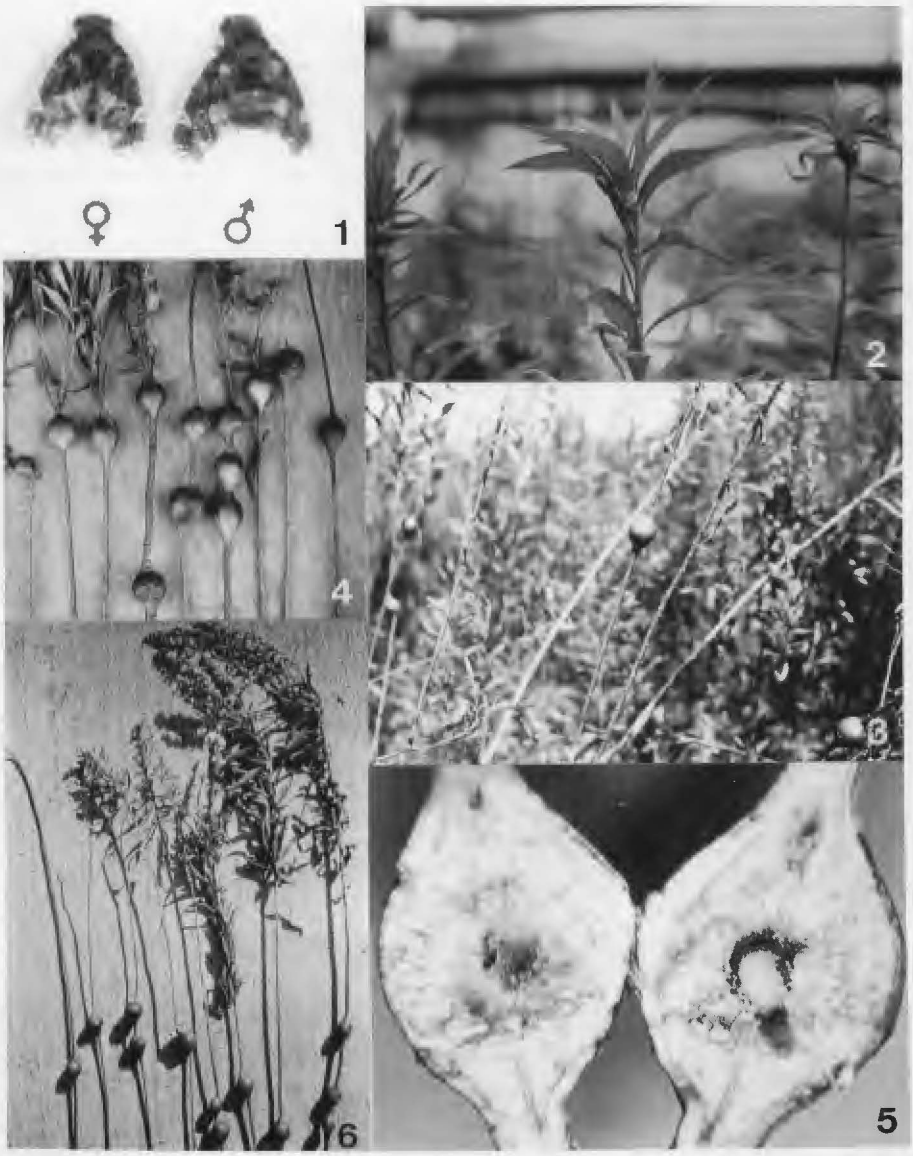
Larval weight (mg)				
September	October	November	December	January
26.8±1.2	53.8±1.1	60.2±1.0	64.5±1.0	49.6±0.8

Mean ± SE. N = 80 to 120

Pupa: The early pupa is frequently referred to as a pre-pupa. At first the anterior of the pupa is light yellow-green and the posterior white. Later, the pupa becomes uniform light tan and then turns dark brown to black. Its length was about 6 mm.

Life cycle

Emergence of the adults at coastal Texas occurred in March. Adults allowed to emerge in the laboratory were relatively inactive and did not fly with normal vigour. Gall formation appeared localized. That is, gall clusters appeared in the same area, suggesting that an individual adult's distribution is very limited. Uhler (1951) has reported that eggs hatch within five days



PLATE

1 Adult of *E. solidaginis*
2 Ball gall(s) on goldenrod, May
3 ditto, September
4 Ball galls on a stem of goldenrod
5 Hibernating larvae of *E. solidaginis* in a ball gall
6 Efflorescence of ball gall-bearing goldenrod

at 25℃ and seven days at 20℃ after oviposition. After hatching, the larva bored into the terminal bud and began to enlarge a chamber for itself. During this period a ball gall formed on a stem of the goldenrod with the growing larva and host plant (Plate 2, 3). In most cases a single ball gall is found on a host plant; however, two or three ball galls may be found (Plate 4). The hibernating larva began the preparation of the adult exit tube in October or November with completion in January (Plate 5).

The size of the ball galls (December) ranged between 3.8 × 3.0cm (major axis × minor axis) and 2.0 × 1.7cm. In the smaller galls larvae were rarely observed but parasitoids were present. Parasitized galls are known to be of a reduced size compared with unparasitized ones (Stinner and Abrahamson, 1979), accordingly, larvae are not usually observed in the ball galls smaller than 2.0 × 1.7cm.

TABLE 2 Parasitoids attacking *E. solidaginis* in three different sites during September to November

Species	Site			Total No.	Parasitism (%)
	1	2	3		
Modellistena unicolor	129	22	76	227	28.4
Eurytoma obtusiventris	25	13	44	82	10.4
Eurytoma gigantea	33	12	8	53	6.6
Empty	102	89	31	222	27.8
Unparasitoid (*E. solidaginis*)	81	33	100	214	26.8
Total parasitism (%)	78.1	80.5	61.4		73.2

Three insect species preying upon *E. solidaginis* larvae in coastal Texas were identified (Table 2). An additional parasitoid may exist since many galls were emptied by September when studies were initiated.

Effect of E. solidaginis larvae on the efflorescence of the goldenrod

Effect of the larvae on the efflorescence of the goldenrod was investigated (Table 3). Above 90% of ball gall-bearing plants except two sections flowered and there was no significant difference in the efflorescence rate between gall-bearing and non-gall-bearing plants. Furthermore, flowers were out on even three-ball-gall-bearing plants (Plate 6). Although the formation of galls appeared not to affect efflorescence in this investigation, it is said to lower seed reproduction (Hartwett and Abrahamson, 1979), showing that reducing spread and replacement of the goldenrod by seeds can be expected. Since the goldenrod can also spread by extension of rhizomes, insects which can attack these subsurface structures or feed on new buds in early spring may be highly efficient in the

TABLE 3 Effect of *E. solidaginis* larvae on the efflorescence of goldenrod

	Observation date	Observation stem (No.)	Efflorescence		Efflorescence rate (%)
			Present	Absent	
Gall-bearing	October 13	100	92	8	92
		100	91	9	91
		100	90	10	90
		100	65	35	65
	October 21	100	98	2	98
		100	96	4	96
		100	78	22	78
	Average				87.1
Non-gall-bearing stem	October 13	500	468	32	93.6

control of this weed(Takafuji, 1978). Formation of the gall significantly reduces the number of new rhizomes produced (Hartwett and Abrahamson, 1979). Furthermore, in early spring the host plants parasitized with the larvae reduced both growth and the degree of allopathic inhibition of other weeds. *E. solidaginis* may therefore be an effective natural enemy useful in the biological control of the goldenrod (Naito, personal communication).

It is necessary in Japan to survey the general relations existing between the fly and the host plants, e.g. minute mutuality between the native plants and the fly, differential climatic effect on the fly coexisting with the host species, parasites to the fly and etc. (Abrahamson et al., 1983) and then the possibility of controlling the goldenrod by *E. solidaginis* should be further discussed.

SUMMARY

To introduce the general biology of the host specific parasitic insect, *Eurosta solidaginis* and the information that partial control of the introduced goldenrod (*Solidago* sp.) weed may be accomplished by the introduction of this insect, the basic aspects of the ecology of this species were studied.

Preliminary data are presented to the general biology of one population of this insect-plant association.

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