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Factors Affecting the Distribution of the Goldenrod Fly, Eurosta Solidaginis (Fitch) (Diptera: Tephritidae), That Forms in the Tall Goldenrod, Solidago altissima L. (Asteraceau)

Chin Yang
College of DuPage

Factors Affecting the Distribution of the Goldenrod Fly, Eurosta Solidaginis (Fitch) (Diptera: Tephritidae), That Forms in the Tall Coldenrod, Solidago altissima L. (Asteraceau)

by Chin Yang

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The Assignment: Conduct experimental research and author a paper about the project that follows a professional format.

ABSTRACT

The study examined the factors relating to the distribution of *Eurosta solidaginis*, the goldenrod gallfly that forms on *Solidago altissima*, the tall goldenrod. Various biological and environmental factors were examined for this study. The results showed that *E. solidaginis* was not the dominant parasite and it showed the presence of some multiple *E. solidaginis* galls, which may indicate the presence of resistant genotypes of *S. altissima*. The presence of a resistant host genotype may increase intraspecific competition for viable goldenrod hosts and the multiple ovipositing of eggs into the same host plants that lead to necrosis caused by the host plant. The results also showed that environmental variables such as light saturation and soil temperature might be factors contributing to the distribution of *E. solidaginis* galls.

INTRODUCTION

In a host-parasite system, parasites can have detrimental impacts on the host plant population. Some attack by grazing, starving the host of essential nutrients and some are vectors of disease. In the early twentieth century, the chestnut blight fungus, *Cryphonectria parasitica*, had a devastating effect on the American chestnut, *Castanea dentate*, bringing it to the brink of extinction. Within the first fifty years of the twentieth century, the Chestnut blight had swept across the eastern deciduous forests, leaving 3.6 million hectares of American chestnut trees dead or dying (Solomon et al., 2002; Simms, 1996). More recently in the United States, the pine wilt nematode has been devastating pine tree populations by rapidly reproducing and moving into the vascular system of trees, stopping water and nutrient flow to all above ground plant parts causing death within one month (Cerny, 1994). Understanding and determining parasite distribution is important to understanding plant distribution, thus the factors determining the distribution of parasites are of great interest and is the focus of this research study.

This study focused on the tall goldenrod, *Solidago altissima*, an abundant species of goldenrod found in old fields throughout the Eastern and Midwestern parts of the United States (Weis and Abrahamson, 1998). Individual fields of goldenrod normally contain many genetically distinct clones, each of which may consist of a few to hundreds of ramets derived from an extensive system of rhizomes (Anderson et al., 1989). Patches of the perennial clonal herb are commonly found infested by galls, abnormal growths of plant tissue, induced by parasitic insects. The gall making insects stimulates the host plant through a complex chemical interaction (Schnick and Dahlsten, 2003). The goldenrod gallfly, *Eurosta solidaginis*, is one of the parasites of the tall goldenrod that induces cecidogenesis.

The goldenrod gallfly gall is recognized by the presence of one or two spheroid-shaped galls on the stem of the plant, typically about 2 cm in diameter. The insects' relationship to the plant is a parasitic one because while the tumor-like growth supplies the larva with food and shelter, the plant receives no benefit in return. As a consequence, the plant produces fewer seeds than an unafflicted plant and grows more slowly because the galls are produced at a cost of photosynthate and energy to the host plant (Weis

and Abrahamson, 1998; Schnick and Dahlsten, 2003).

The lifecycle of the goldenrod fly begins in early spring when the larvae, which has overwintered in the previous seasons galls, pupates and emerges in May (Weis and Abrahamson, 1998). A male fly seeks out the tip of a newly growing goldenrod stem and flicks his wings to lure a female. After mating, a female carefully seeks out suitable tall goldenrod stems that are reactive to gall stimulation. This is a complex process and must be done carefully to insure the survival of the larvae, because not all genotypes of the tall goldenrod are equal; some exhibit a range of host suitability for the larva, from susceptible to highly resistant (McCrea and Abrahamson, 1987; Anderson et al., 1989; Hess et al 1996; Weis and Abrahamson, 1998). Resistant plants kill off the abnormal gall tissue and the larvae dies without the nutrition provided by the forming galls.

Hess et al. (1996) found that the unsuitability of many *S. altissima* genotypes for larval development may constrain populations of *E. solidaginis* to a few acceptable host genotypes and increase levels of intraspecific competition. High levels of intraspecific competition gave rise to tissue necrosis (plant resistance mechanism induced by high levels of larvae infestation on the host plant), multiple-gall formation on a host plant by different females, and female gall flies ovipositing into less preferred genotypes of *S. altissima* (Zurovchak and Shealer, 1996; Hess et al 1996). Contest competition existed among *E. solidaginis* larvae inhabiting *S. altissima* with double galls, with the top galls being smaller than the bottom galls due to the bottom galls intercepting the majority of the resources (Zurovchak and Shealer, 1996).

There are other parasites of the tall goldenrod that also forms galls: the goldenrod gall midge, *Rhopalomyia solidaginis*, which forms flower-like galls at the terminal bud of the stem and the goldenrod gall moth, *Gnorimoschema gallaesolidaginis*, which form oblong galls on the upper stem region. Interspecific competition for the same resources may decrease the distribution of *E. solidaginis*.

This study was concerned with *E. solidaginis*. It was anticipated that the distribution of *E. solidaginis* would be related to the distribution of its host and negatively related to its competitors, *R. solidaginis* and *G. gallaesolidaginis*. However, patch size and physical variables were also examined as to narrow the factors affecting the distribution of the goldenrod gallfly that forms galls on the tall goldenrod.

METHODS

The study location was the naturalized areas on the campus of the College of DuPage, Illinois (41°45’00” N, 88°00’00” W). These areas, which cover about 15 hectares, have been maintained for 30 years as marsh, successional woodlands, and tallgrass prairie. The area was previously farmed. The stands of tall goldenrod growth consisted of early successional fringes to wetland, tallgrass prairie and woodland. The data collection for this study was conducted in April 2003. Twenty-four sample patches were studied and whenever possible ten one-square meter quadrants were examined within each patch.

Selected physical measurements were taken in the center of patches to determine their correlation with *E. solidaginis*. The variables examined in this study were: the number of *E. solidaginis*, the counts of other parasites of the tall goldenrod, number and combination of multiple galls, soil surface temperature, air temperature, light, soil pH, moisture, height of the host, variability of the floral environment, and the organic contents of the soil. The presence of other parasites of *S. altissima* may cause interspecific competition, while the presence of multiple *E. solidaginis* galls may indicate intraspecific competition. Environmental variables were examined because they may affect the suitability of the plant for ovipositing by *E. solidaginis*.

The heights of the flora in patches, which included plants other than *S. altissima*, were characterized by a ranking scale of 1 – 5, where 1 was assigned to a site where flora did not exceed 8 cm in height, 5 was assigned if flora exceeded 15 m, and intermediate rankings were assigned when heights ranged in between 8 cm and 15 m. The variability of floral environment was investigated because the size of the plants surrounding *S. altissima* may prevent *E. solidaginis* from detecting *S. altissima* in a given area, which may also affect the distribution of the fly gall. The variability of the floral environment

ranking in view of plants heights were measured on a 1 through 3 scale, where 1 was assigned when no deviation in height was apparent and 3 was assigned when the heights of the plants varied greatly in a given patch.

The soil surface temperature (within 3 cm), air temperature and light saturation were measured using a LogIt meter (DCP Microdevelopments Ltd., Norfolk, UK). The soil pH was measured using a Kelway meter (Kelway Instruments Co., Japan). The soil moisture was measured using an Aquaterr Instruments Moisture Meter (Aquaterr Instruments Incorporated, Costa Mesa, CA). Finally, the fraction organic content of the soil was determined as the loss in weight after oven drying surface samples at 60^{o}C to a constant weight and then burning the samples at 600^{o}C for 6 hours in a muffle furnace.

The relationships between the counts of the goldenrod fly/patch and the selected biotic and abiotic variables were tested for significance using Spearman Rank Correlation.

RESULTS

Table 1 shows the biological variables and the means and standard deviations of the physical measurements taken. *E. solidaginis* and *R. solidaginis* galls were common in the survey area, while *G. gallaesolidaginis* were rare. Multiple *E. solidaginis* gall counts and other multiple gall combinations were also rare compared to single gall counts. The environmental variables were consistent for the study period.

Table 2 provides the Spearman Ranking Correlation between the counts of *E. solidaginis* gall counts per patch and the selected biotic and abiotic measurements. The results points to a significance between *E. solidaginis* counts per patch and *S. altissima* counts per patch as well as the counts of the other gall insects. Soil surface temperature and the light saturation also were related to the distribution of *E. solidaginis.*

DISCUSSION

The results showed the presence of multiple *E. solidaginis* galls, although they were few in number. The low number of multiple *E. solidaginis* galls, in combination with a positive correlation of *E. solidaginis* galls to other gall making insects, does not indicate contest competition. The results also showed a great variation in *E. solidaginis* counts per patch and negative correlations of *E. solidaginis* counts to the height ranking and variability of floral environment ranking may indicate the presence of resistant genotypes of *S. altissima*. The various patch areas that we studied could have contained ramets derived from the rhizomes of resistant genotypes of *S. altissima*. The presence of a resistant host genotype and intraspecific competition for the same valuable resources may decrease the possibility of gall formation due to necrosis caused by the host plant, which affects the distribution of galls, or create multiple galls to be formed on the host (Hess, M. et al 1996). This could be the reason for *R. solidaginis* being the dominant parasite, not *E. solidaginis*.

The data showed that there were correlations between *R. solidaginis* counts/patch, *G. gallaesolidaginis* counts/patch, and *R. solidaginis* and *G. gallaesolidaginis* counts/patch with *E. solidaginis*. However, in light of the fact that these parasites oviposit at different times than *E. solidaginis*, with *R. solidaginis* ovipositing in late summer and *G. gallaesolidaginis* ovipositing in fall, these correlations may not be significant in the study of the factors related to the distribution of the fly gall.

The experiment did not provide conclusive evidence between most of the environmental factors and the distribution of the fly. The environmental variables were measured in the spring after gall formation, not during the prime growth period of the galls and plants, which minimizes the significance of the environmental variables. The only consistent factors at a given point in a season may be light saturation and soil surface temperature of a given area. These may be some of the factors considered in the complex process of selecting a favorable stem for ovipositing of an egg by the female *E. solidaginis*. The right

conditions are conducive for the survival of offspring and perhaps the female fly takes some of these factors into consideration before ovipositing eggs into the goldenrod stem. Future research should scrutinize the environmental factors observed in this study, during the peak period during gall formation to determine the significance of the factors and the distribution of the galls.

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Table 1. Summary (x ± s; all n = 24 unless noted otherwise)

Variable	**x ± s**
Eurosta solidaginis counts/patch	125 ± 199
Solidago altissima counts/patch	1930 ± 2574
Rhopalomyia salidaginis counts/patch	634 ± 1317
Gnorimoschèma gallaesolidaginis counts/patch	7.87 ± 15.10
Multiple *E. solidaginis* counts/plant/patch	0.21 ± 0.66
E. solidaginis + *R. salidaginis* counts/plant/patch	1.33 ±3.42
Multiple *R. salidaginis* counts/plant/patch	1.54 ± 5.45
R. salidaginis + *G. gallaesolidaginis* counts/plant/patch	0.04 ± 0.20
Patch area (m^2)	77.7 ± 101.0
Soil surface temperature (°C)	12.4 ± 4.0
Air temperature (°C)	23.3 ± 3.0
Light saturation (%)	90.5 ± 3.5
pH	6.12 ± 0.21
Moisture saturation (%)	73.5 ± 7.6
Height ranking	2.40 ± 0.49
Variability of floral environment ranking	2.02 ± 0.71
Fraction organic content of soil	0.105 ± 0.039; n = 23

Table 2. Spearman rank order correlations (r) between counts of Eurosta solidaginis counts/patch and the various biotic and physical measurements. All df = 22 unless noted otherwise. Significance was determined at $p \leq 0.05$.

Biotic or physical measurement	**r**	**p**
Solidago altissima counts/patch	0.847	<0.001
Rhopalomyia salidaginis counts/patch	0.848	<0.001
Gnorimoschèma gallaesolidaginis counts/patch	0.505	0.012
R. salidaginis + *G. gallaesolidaginis* counts/plant/patch	0.850	<0.001
Patch area (m^2)	0.846	<0.001
Soil surface temperature (°C)	0.569	0.004
Air temperature (°C)	0.347	0.097
Light saturation (%)	0.408	0.048
pH	0.293	0.165
Moisture saturation (%)	-0.066	0.760
Height ranking	0.105	0.626
Variability of floral environment ranking	0.082	0.679
Fraction organic content of soil	-0.156 (df = 21)	0.478