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Investigating the Factors That Determine the Distribution of the Stem-Galling Tephritid Fly in an Old Field in Northeastern Illinois

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by Marsella Jorgolli

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The Assignment: Conduct original research and write a paper about the research that follows a format in a particular scientific journal.

Abstract

This study investigated ecological variables associated with the distribution of *Solidago altissima* and galls of *Eurosta solidaginis*. This parasite-insect forms galls in stems of *S. altissima*. *S. altissima* was found to be positively correlated to soil moisture and negatively correlated to surface soil temperature. Using Spearman rank correlation, the distribution of *E. solidaginis* was found to be positively correlated to soil pH, the distribution of another gall-making fly *Rhopalomyia solidaginis,* and to surface soil temperature. Both species showed clumped distribution but they were not correlated in density.

Introduction

A goal of evolutionary ecology is to understand how the magnitude and direction of natural selection may vary in response to basic ecological processes (Kapelinski et. al. 1994). An understanding of the structure of selection regimes can aid in assessing natural selection's place among the causes of evolution. Herbivorous insects have long been the subjects of speciation models and of tests of the predictions of these models (Abrahamson et. al. 1993). The basic processes of speciation in herbivorous insects are poorly understood, despite long debate (Craig et. al. 1997).

The plant-insect interaction under study in this investigation is the tall goldenrod (*Solidago altissima*) the gall-making parasite*, Eurosta solidaginis* (Diptera: Tephritidae) (Cain 1990). Some 130 species of goldenrods are found throughout the Northern Hemisphere, with the largest concentration right in this country. They range in height from mere centimeters to several meters; the family resemblance is remarkably strong (Egli et. al. 1998). Most goldenrods are upright in form, each branching stem tipped with arching spikes or whirling panicles of yellow flowers produced from midsummer into autumn (Lovejoy 1994). *S. altissima,* known as the tall goldenrod, propagates vegetatively by persistent rhizomes that produce annual shoots (Meyer and Schmid 1999). Initial colonization of a site by *S. altissima* involves the establishment of genets from seeds, but subsequent population development usually occurs only by the production of ramets via clonal growth (Meyer and Schmid 1999). It is a broadly distributed, native, rhizomatous, perennial forb (Kapelinski and Weis 1994). Throughout the northeastern United States and adjacent Canada, this goldenrod is often the dominant plant in old fields and pastures during the first 15-20 yr following abandonment (Root 1996). Independent and adaptable, goldenrods thrive in ordinary garden soils and even poor soils. They are firmly drought resistant once established (Lovejoy 1994).

The goldenrod gall-making fly (*E. solidaginis*) is a common and widely distributed insect found coast to coast in the central part of North America. This insect parasitizes the stems of the goldenrod plants causing the plant to produce a large spherical gall on its stem. The adult flies emerge from their galls in late spring. They only live about 2 weeks, during which time they mate and the females lay their eggs. An egg is deposited at terminal bud of the emerging goldenrod stems. The larva emerges in about ten days and immediately begins to eat from inside the stem of the goldenrod. The saliva of the larva has chemicals, which cause the plant to grow abnormally, creating a spherical gall that the larva lives within. The larva will exploit the goldenrod stem for a full year before becoming adult. The emerging larva then tunnels through the bud to just beneath the apical meristem. The third-instar larva exhibits a distinct winter diapause to avoid extreme cold temperatures (Craig and Horner 1997). Mature adults emerge from the galls during the following spring. The insect, by exploiting the plant environment, leads to reduced flower and seed production by the goldenrod.

Larval survival and growth are determined, in part, by aspects of host-plant quality, and host-plant quality for herbivores is frequently altered by water deficits (Abrahamson and Horner1999). Goldenrod gall flies have many predators and competitors, such as parasitoids, parasites and birds, some even when they are in the larval stage in their gall. A potential competitor is the goldenrod gall midge (*Rhopalomyia salidaginis*), which forms flower like gall at the terminal bud of the stem (Root 1996).

The ability of a species to colonize and establish within an area is directly related to the conditions of that specific environment. The objective of this study was to investigate factors associated with the distributions of *S. altissima* and galls of *E. solidaginis* to include those biological and physical. Galls of *R. solidaginis* were included in analysis as the midge is a potential competitor of *E. solidaginis* based on parasitism of a common host. Physical measurements were those that commonly define climate to include soil temperature, moisture, and light exposure.

Methods

The study site was an old field located in the campus of College of DuPage, Illinois. The old field has been left to undergo natural succession for 15 years on top of construction debris evacuated during building activities. The sampling was done in April 2004.

Transects of the study area were randomly chosen and fifty 1m^2 plots were measured in each for counts of *S. altissima*, galls of *E. solidaginis* and *R. solidaginis* as well as physical measurements of soil pH, temperature, moisture and light exposure. The physical measurements were taken during the morning and at noon to account for changes through the day. Soil pH was measured with a Kelway pH meter (Kelway instrument Co. Japan). Temperature measurements were taken at different depth to look for alternations in correlations with the distribution of the goldenrod and galls of *E. solidaginis.* Moisture and 10 cm soil temperature was measured with Aquaterr Temp-200 (Aquaterr Instruments, Costa Mesa, Ca). Light percentage and surface soil temperature was measured with Log IT Datameter 1000 (DCP Microdevelopments Limited, Norfolk, UK).

Patterns of dispersion for *S. altissima* and galls of *E. solidaginis* were determined from variance to mean ratios from count data. Spearman rank correlation was used to determine relationship between counts of tall goldenrods per square meter and *E. solidaginis* per square meter to the selected abiotic and biotic measurements.

Results

A summary of the measurements taken for counts of goldenrods, galls and midges, as well as selected physical factors is given in Table 1. The variance to mean ratios for tall goldenrod and galls of *E. solidaginis* were 10.72 and 1.8, respectively, indicating both had a clumped distribution. Even though both were clumped, they were not correlated in distribution (Table 2).

Counts of tall goldenrod were positively correlated to morning soil moisture and negatively correlated to noon surface temperature (Table 1). The gall count of *E. solidaginis* was positively correlated to morning surface temperature, gall counts of *R. solidaginis,* and the soil pH.

Discussion

There was no evidence to conclude that patterns of occurrence and abundance of both the fly and goldenrod were shaped by light exposure, even though some other studied have shown that increasing irradiance affected the growing patterns of the goldenrod, especially of its rhizomes (Egli et. al. 1995). Another consistently non-significant factor was deep soil temperature. Possibly *S. altissima* might be less deeply rooted than 10 cm where measurements were taken.

The positive correlation between counts of *E. solidaginis* and *R. solidaginis* fails to indicate competition was affecting their distribution. These results are paralleled by Root's (1996) who, in his study, concluded that insect herbivores did not, in any way, impact the density of stems. This might be because *E. solidaginis* may form host races on another goldenrod species *Solidago gigantean,* whose distribution was not considered in this study. The absence of significant interactions between these two potential competitors may be due to their low abundances.

The positive correlation of the values of pH with the fly distribution might suggest a correlation of the fly genetic types of *S. altissima* that prefer particular pH conditions plant. This might come due to the existence of various genetic groups of tall goldenrod with different resistance abilities resulting in different levels of suitability with the fly.

In other studies it has been found that larval survival and growth are determined, in part, by aspects of host-plant quality, and host-plant quality for herbivores is frequently altered by water deficits, implying a positive correlation between soil moisture and insect abundance (Horner and Warren 1999). The same results were obtained in this study. Even though soil moisture obtained significance to goldenrod distribution only for the morning measurements, the afternoon value was still positive. The negative correlation with the surface soil temperature also supports a link between soil moisture and tall goldenrod density.

Conversely, *E. solidaginis* had a positive correlation with surface soil temperature, suggesting that this species can resist dry environments. This occurrence might be adaptive in nature as to avoid potential competitors and predators and live in an environment with low levels of parasitism and competition (Schmid 1994). This correlation might also indicate a dependence of oviposition levels and emergence of larvae to temperature.

A number of other factors may determine the relative abundance of *E. solidaginis* making it difficult to explain distribution of this species based on the factors included in this study alone. Further studies examining factors such as predation on *E. solidaginis*, genetic variation among *S. altissima* populations, and other plant and habitat characteristics might offer to more completely explain the distribution patterns of *S. altissima* and *E. solidaginis.*

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Table 1. Summary ($\bar{x}$ ± SD; all n=50) of the counts of goldenrod, gall counts of *Eurosta solidaginis*, gall counts of *Rhopalomyia Solidaginis*, and of the measurements of the physical and biotic factors.

Variable	8:00 a.m.	Noon
	Mean ± S. D.	Mean ± S. D.
Solidago altissima (gall counts/m^2)	28.17 ± 17.38	28.17 ± 17.38
Eurosta solidaginis (gall counts/m^2)	0.88 ± 1.26	0.88 ± 1.26
Rhopalomyia Solidaginis (counts/m^2)	19.46 ± 17.07	19.46 ± 17.07
pH	6.621 ± 0.296	6.621 ± 0.296
10cm Soil Moisture %	76.62 ± 6.40	67.78 ± 10.25
10cm Soil Temp. (ºC)	17.76 ± 1.13	11.00 ± 4.68
Surface Soil Temp. (ºC)	9.14 ± 2.13	19.52 ± 4.42
Light Exposure	84.48 ± 3.03	89.20 ± 1.46

Table 2. Spearman rank correlation analysis between counts of tallgoldenrods/m^2 and selected variables.

Variable	8:00 a.m.		Noon	
	Solidago Altissima/m^2	Galls of *E. Solidaginis*/m^2	*Solidago Altissima*/m^2	Galls of *E. Solidaginis*/m^2
Eurosta Solidaginis (gall counts/m^2)	0.12		0.12	
Rhopalomyia Solidaginis (gall counts/m^2)	0.20	*0.33	0.20	*0.33
Ph	-0.02	*0.29	-0.02	*0.29
10 cm Soil Moisture %	*0.34	-0.15	0.19	-0.21
10cm Soil Temp. (ºC)	0.03	0.01	0.02	0.02
Surface Soil Temp. (ºC)	-0.09	*0.62	*-0.29	0.21
Light Exposure	-0.03	0.23	0.06	-0.01

* -- Significant values showing positive or negative correlation between the variables and the goldenrod or the gall fly