

The densities of goldenrod galls (*Eurosta solidaginis*) and their goldenrod host plants (*Solidago canadensis*) while directly related to each other, are not impacted by soil nitrogen or soil moisture

Tatia Bauer

University of Michigan Biological Station

EEB 381 General Ecology

August 19, 2010

Cathy Bach

Abstract

The purpose of this study was to determine the effects that soil moisture and soil nitrogen content had on the density and abundance of goldenrod galls (*Eurosta solidaginis*) on their host plant goldenrod (*Solidaginis canadensis*) near the shores of Lake Michigan. I tested the relationship between the number of goldenrod plants and number of galls, the soil moisture and gall density, the soil nitrogen content and gall density and the total number of galls and number of double galls. Plots were found in Cross Village Park, Cross Village, MI at varying of distances along transects. I counted the total number of goldenrod plants, how many galls were present and also recorded the occurrence of double galls in each plot. Soil samples were also taken to determine soil moisture and nitrogen content.

There was a direct, significant relationship between the number of goldenrod plants and goldenrod galls and also with the total number of galls and number of double galls. There was no significant correlation between soil moisture and gall density or with soil nitrogen content and gall density. In conclusion, only the numbers of goldenrods significantly influenced the distribution of goldenrod galls, which then influenced abundance of double galls; however soil moisture and nitrogen content had no affect on gall density.

I grant the Regents of the University of Michigan the non-exclusive right to retain, reproduce, and distribute my paper, titled in electronic formats and at no cost throughout the world.

The University of Michigan may make and keep more than one copy of the Paper for purposes of security, backup, preservation and access, and may migrate the Paper to any medium or format for the purpose of preservation and access in the future.

Signed,

INTRODUCTION

The size and distribution of plant parasite populations are directly related to the quality of the plants on which they prey. Many factors contribute to this quality such as water availability and access to nitrogen—a limited nutrient in terrestrial environments. Limited soil moisture can lead to lowered plant fitness or mortality, depending on the severity of the drought according to Saha et al. (2008). However Bollinger et al. (1991) found that certain perennial plants were more successful in areas not watered after a drought. Just as water availability can have mix results on plant growth, so can nitrogen availability. Nitrogen addition increased photosynthetic and relative growth rates in hybrid plants in a Campbell et al. (2010) study. Stevens et al. (2006) observed more nitrogen within plant biomass as soil nitrogen increased, suggesting a utilization of available nutrients, and Meyer and Root (1993) also highlighted nitrogen's role in both increasing plant biomass and the amount of seeds produced. However, Huberty et al. (1998) found that additional nitrogen had no effect on the amount of nitrogen within plant biomass in perennial plants, which suggests some plants have adapted ways to grow with low nitrogen levels. While both water and nitrogen availabilities directly affect the quality of plants, these factors also indirectly affect the presence of plant parasites, such as insect galls which use their host plant as a source of energy (Tooker et al. 2008).

Gall-forming insects, which are very prevalent across plant populations, are commonly wasps, flies, thrips and aphids (Price 2005). A female will oviposit an egg onto the host plant; after 7-12 days a larva emerges and bores into the plant tissue (Abrahamson et al. 1983). Once inside, the larva releases a chemical that stimulates production of extra plant tissue over the larva—creating the gall (Abrahamson et al. 1983). The larva then feeds on highly nutritious inner tissues of the plant while developing inside the gall (Herrera and Pellmyr 2002). Galls can therefore be used as potential indicators of overall plant fitness and nutritive value as the female gall-forming insect will select the most nutritive

plant on which to oviposit since it will best supply her offspring with nutrients until it emerges as an adult (Herrera and Pellmyr 2002).

Such an example a gall-forming insect exploiting the resources of its host plant is the goldenrod gall fly (*Eurosta solidaginis*) which uses goldenrod (*Solidago canadensis*) as its host plant (Weis et al 1992). This species follows the general life pattern of the gall insects and like most, the success of the developing larvae depends on the amount of nutritive tissue produced by *Solidago Canadensis* which it uses as a food source (Herrera and Pellmyr 2002). It is likely then, that the maternal fly will select for goldenrods that have the most resources available to them in order to better the chances of her larvae's survival, and this species will even deposit multiple eggs on one goldenrod plant (Gilbert and Kurewski 1986). According to Abrahamson et al. (1983), the density of galls is directly related to the number of goldenrod plants present; this suggests that the presence of more goldenrod plants indicates to a female *Eurosta solidaginis* that the area has more nutrients to support her young. Along with lower goldenrod plant abundance, drought was found to significantly decrease the abundance of *Eurosta solidaginis* by Sumerford et al. (2000).

The purpose of this study is to investigate the effects of soil moisture and soil-nitrogen content on the density and abundance of goldenrod fly galls (*E. solidaginis*) on goldenrod plants (*S. canadensis*) on the shores of Lake Michigan. Based on the findings of Abrahamson et al. (1983) which indicate a direct relationship exists between goldenrod plant density and goldenrod gall density, I predict that as goldenrod density increases there will also be an increase in gall density. Since the experimental location is in very close proximity to water and low water levels decrease gall abundance (Sumerford et al. 2000), I predict that higher soil moisture will result in a higher density of galls. Soil nitrogen has also been determined to be significant to plant growth (Campbell et al. 2010) and to nitrogen content within plant biomass (Meyer and Root 1993, Stevens et al. 2005), and since animals need to acquire nitrogen to

make proteins essential for their development, I predict that areas with high soil-nitrogen content will have greater gall density. Finally, in the areas with many galls I also predict that there will be a higher occurrence of multiple galls since, though no prior studies have been done to determine this relationship, logically, with reduced amounts of unused plants, some females will choose to add an egg to an already utilized plant.

METHODS

I set up two transects within Cross Village Park in Cross Village, Emmet County, MI, USA extending perpendicularly from the shores of Lake Michigan inland for 600 m that went through abundant goldenrod plant areas. On each transect, I established three regions, also abundant with goldenrod plants, which I designated as a close (30-60m), intermediate (130-160), or far (600-650m) distance from shore. I chose a variety of distances to ensure changes in both soil moisture and nitrogen content. For each distance range on both transects I sampled three 5x5m plots in which I recorded the number of *Solidago canadensis*, the number of *Eurosta solidaginis* galls, and also the number of occurrences of multiple (two or more) galls on one *Solidago canadensis* plant. The far region of both transects intersected due to a bend in the lake shoreline so I set up six plots in that one region and randomly assigned each to a transect. To determine soil moisture and percent nitrogen content for each plot, I collected a soil sample: I used a soil corer to removed the soil to the depth that corresponded with the length of goldenrod roots observed in each plot (approximately 20cm); then I massed each of the samples on site with a pesola scale, let them dry in a 60°C oven overnight and remassed each sample; the difference in masses was then the amount of water that was present in the soil, and each mass divided by its dry weight was the percent moisture of the sample. To determine percent soil nitrogen, I pulverized each dry sample to a powder consistency using a SPEX CertriPrep 8000D ball mill,

and then I put 2ml of the powder in labeled glass vials and submitted them to the University of Michigan Biological Station's Lakeside Laboratory to be analyzed for nitrogen content.

I used SPSS to test my hypotheses by conducting linear regressions between number of goldenrod plants and number of galls, soil moisture and gall density (# of galls/m²), nitrogen levels and gall density, and number of galls and double galls.

RESULTS

The relationship between the number of goldenrod plants and number of galls was significant ($R^2 = .409_{18}$, $p = .004$) and there was a strong positive correlation (Figure 1). Soil moisture did not significantly influence the density of galls ($R^2 = 4.46E-4_{18}$, $p = .934$). Even though soil moisture varied from 9.6% to 80.9%, it had no effect on gall density (Fig. 2). The relationship between percent nitrogen and gall density was not significant ($R^2 = .141_{18}$, $p = .125$), although there was a negative trend in the effect of nitrogen on gall density (Fig. 3). The number of double galls was directly related to the amount of galls present ($R^2 = .699_{18}$, $p < .001$, Fig. 5). 69.9% of the variation found in numbers of double galls was explained by the number of galls.

DISCUSSION

The results of significantly higher gall abundance with higher number of goldenrod plants supported my original hypothesis. My findings correspond to those of Abrahamson et al. (1983) that gall density is directly related to the density of the goldenrod plant. These results suggest that high goldenrod plants are more attractive to female gall flies when ovipositing eggs.

My prediction of a direct relationship between soil moisture and gall density was not supported by the data and does not follow observations of lower plant fitness in dry conditions by Saha et al. (2008), and subsequent decrease in exploitive gall density (Sumerford et al. 2000). My lack of

correlation however, could be explained by alternative data found by Bollinger et al. (1991) that showed the growth of perennial plants, such as goldenrod, in an old field were more successful in areas that did not receive the treatment of added water. This suggests that they are able to survive in drier areas and also that their main competitors cannot survive in such a dry habitat. With the plants' ability to survive and thrive in drier soils, it makes sense that gall density was not correlated to soil moisture since their hosts are not reliant on soil moisture.

The prediction that higher nitrogen content would result in a higher density of galls was not supported by my data. In fact the trend was that a higher density of galls was found with lower amounts of nitrogen in soil, although not significant. My results agree with those of Hartley (1992) who also concluded from his study in York, England that no relationship was found between gall densities with the addition of nitrogen, although nitrogen within the plant increased. Abrahamson et al. (1986) also had no indications that the growth of galls was limited by nitrogen. This suggests that nitrogen content is not influencing the oviposition placement by the female gall fly, or the gall larvae success. Some studies, like that of Gilbert and Kurezewski (1986) however, also observed a lower density of galls (multiples specifically) with high nitrogen content. They suggest that high levels of nitrogen can decrease the solubility of amino acids that are found in sap, which decreases the available nitrogen to galls, which could hinder their development—selecting for ovipositions on plants with lower nitrogen content (Gilbert and Kurezewski 1986).

Finally, the positive relationship between the total number of galls and the number of double galls supported my original hypothesis. Although no other study has compared the number of galls and number of double galls, Gilbert and Kurezewski (1986) found that double galls increased in areas with lower amounts of nitrogen which, along with the direct relationship between number of galls and double galls, suggest that both nitrogen and the number of galls affect the abundance of double galls on

goldenrod plants. The correlation between number of goldenrod plants and numbers of galls combined with the known relationship between the number of galls and number of double galls also suggests a direct relationship between the abundance of goldenrod plants and abundance of double galls.

Some possible errors in our findings could have resulted from incorrectly counting the number of goldenrod plants or galls; the 5x5 plots were fairly large and made keeping track of counted and uncounted plants/galls difficult. However, my findings do encourage further study into the nutritional needs of both goldenrod plants and their associated galls. Perhaps a study over a longer interval of time would also be beneficial since my findings cannot predict long-time future or past relationships between goldenrod plants, soil moisture and nitrogen, and galls.

In conclusion, the density of *Eurosta solidaginis*, the goldenrod gall, is significantly correlated to the number of *Solidaginis Canadensis*, goldenrod plants; gall abundance directly affects the number of double galls present. However, gall density is unrelated to soil moisture and soil nitrogen content, providing new data regarding the effect these abiotic factors have on gall-forming insects.

FIGURES

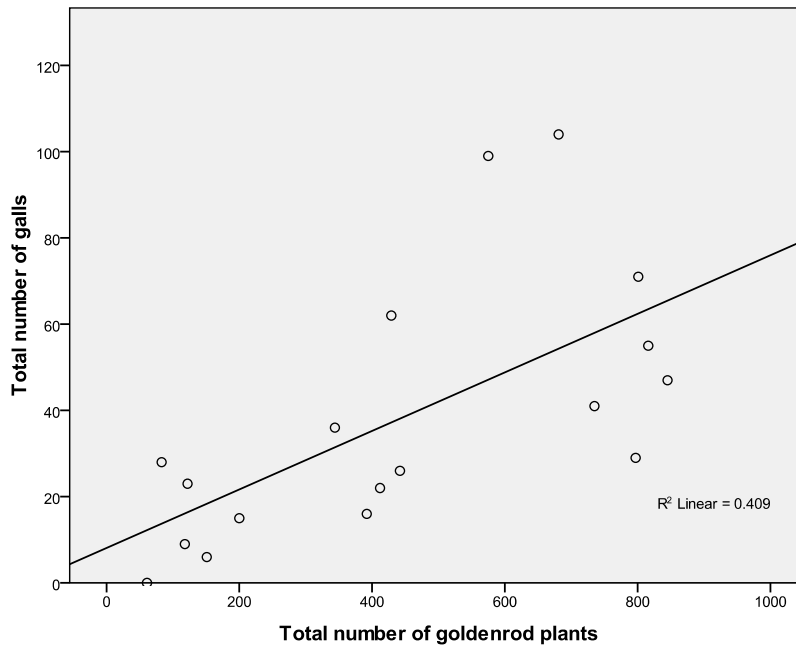


FIGURE 1: The linear regression of number of goldenrods and the total number of galls. There was a significant positive relationship between these variables ($p=.004$).

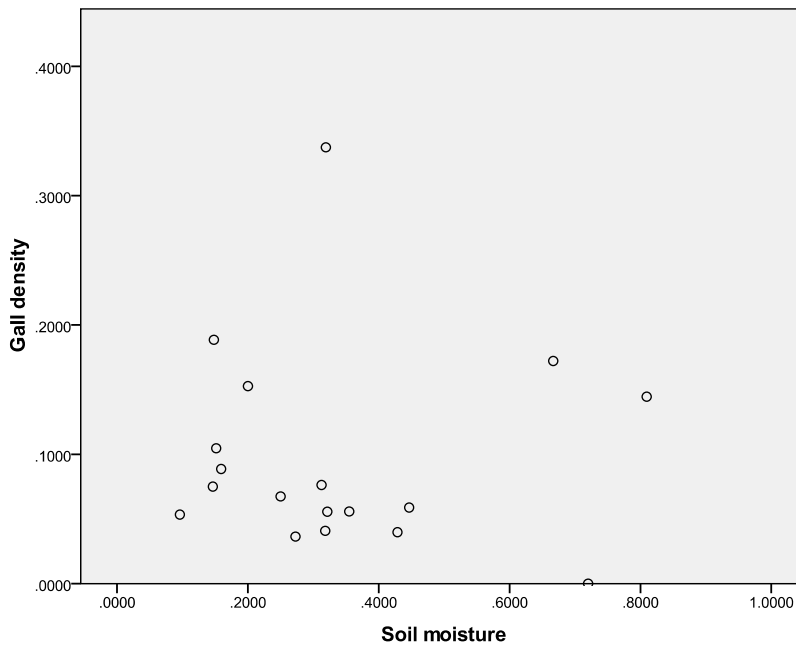


FIGURE 2: The regression of soil moisture and gall density (#galls/m²). Soil moisture did not significantly influence the density of galls in my study sites ($p= .934$). Less than .045% of the variation found in gall density was explained by soil moisture.

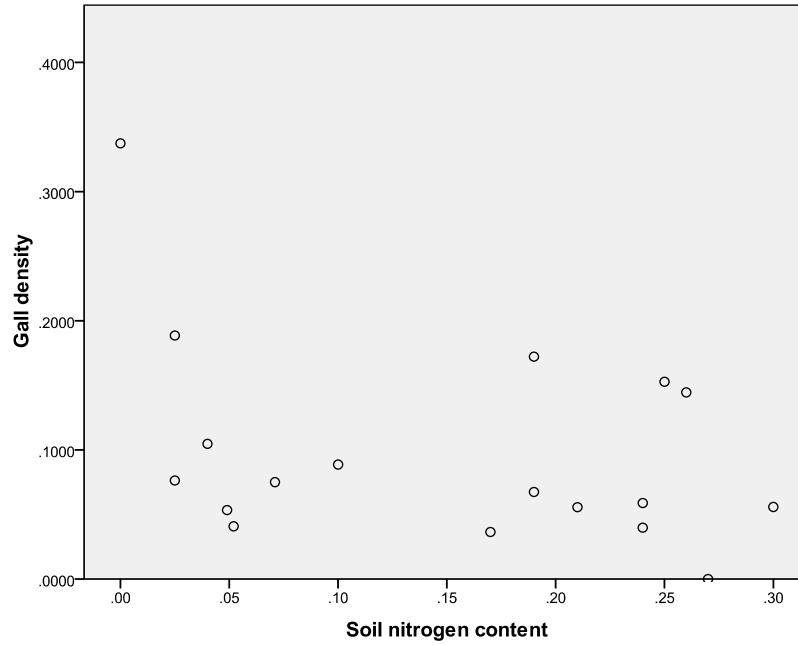


FIGURE 3: The linear regression of gall density related to the percent nitrogen in soil. The trend is greater gall density with lower nitrogen content, but this relationship did not have significance ($p = .125$).

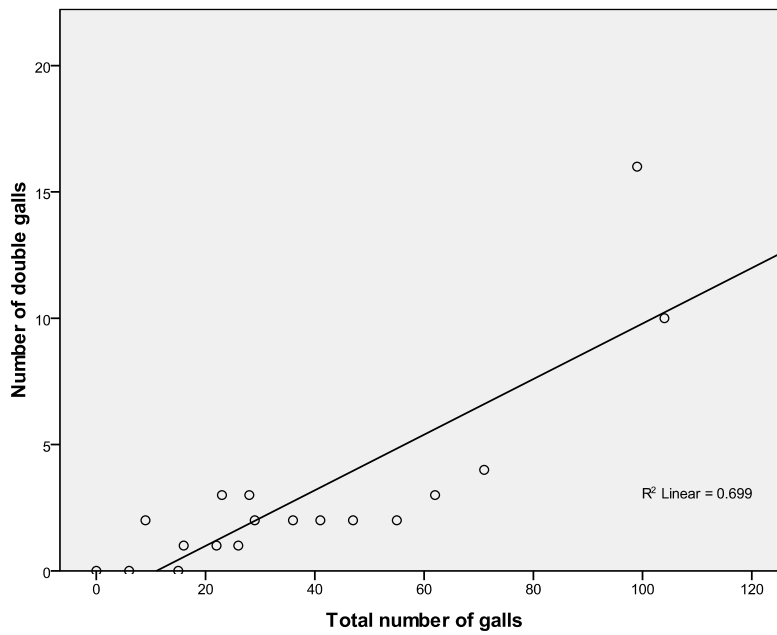


FIGURE 4: The linear regression of total number of galls and the number of double galls. There was a significant positive correlation between the number of galls and the number of double galls present ($p < .001$).

LITERATURE CITED

- Abrahamson, W. G., P. O. Arbruster, and G. D. Maddox. 1983. Numerical relationships of the *Solidago altissima* stem gall insect-parasitoid guild food chain. *Oecologia* 58: 351-357.
- Abrahamson, W. G. and K. D. McCrea. 1986. Nutrient and biomass allocation in *Solidago altissima*: effect of two stem gallmakers, fertilization and ramet isolation. *Oecologia* 68: 174-180.
- Bollinger, E.K., S.J., Harper, G.W. Barrett. 1991. Effects of seasonal drought on old-field plant-communities. *American Midland Naturalist* 125: 114-125.
- Campbell, D. R., Wu, C. A., Travers, S. E. 2010. Photosynthetic and growth responses of reciprocal hybrids to variation in water and nitrogen availability. *American Journal of Botany* 97: 925-933.
- Gilbert, G. S., and F. E. Kurezewski. 1986. Soil nutrient effects on goldenrod galls by *Eurosta solidaginis* (dipteral: tephritidae). *Entomological News* 97: 28-31.
- Herrera, C. and O. Pellmyr. 2002. Plant-animal interactions. Blackwell Science Ltd, Malden, MA, USA.
- Huberty, L. E., K. L. Gross, and C. J. Miller. 1998. Effects of nitrogen on successional dynamics and species diversity in Michigan old-fields. *Journal of Ecology* 86: 794-803.
- Meyer, G. A., R. B. Root. 1993. Effects of herbivorous insects and soil fertility on reproduction of goldenrod. *Ecology* 74: 1117-1128.
- Price, P. W. 2005. Adaptive radiation of gall-inducing insects. *Basic and Applied Ecology* 6: 413-421.
- Saha, S., T. M. Strazisar, E. S. Menges, P. Ellsworth, and L. Sterberg. 2008. Linking the patterns in soil moisture to leaf water potential, stomatal conductance, growth, and mortality of dominant shrubs in the Florida scrub ecosystem. *Plant and Soil* 313: 113-127.
- Stevens, H.M., R. Shirk, and C. E. Steiner. 2006. Water and fertilizer have opposite effects on plant species richness in a mesic early successional field. *Plant Ecology* 183: 27-34.
- Sumerford, D.V., W. G. Abrahamson and A. E. Weis. 2000. The effects of drought on the *Solidago altissima*-*Eurosta solidaginis*- natural enemy complex: population dynamics, local extirpations, and the measures of selection intensity on gall size. *Oecologia* 122: 240-248
- Tooker, J. F., J. R. Rohr, W. G. Abrahamson, and C. M. De Moraes. 1992. Variable selection of *Eurosta's* gall size, I: the extent and nature of variation in phenotypic selection. *Evolution* 46: 1674-1679.
- Weis, A. E., Abrahamson, W. G., and M. C. Andersen. 1992. Variable selection of *Eurosta's* gall size, I: the extent and nature of variation in phenotypic selection. *Evolution* 46: 1674-1697.