

# 2014 年臺灣國際科學展覽會 優勝作品專輯

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參展科別 植物學

作品名稱 **Going Dotty: The Distribution and Effects  
of Rust on Highbush Cranberry**

得獎獎項 二等獎

國 家 Canada

就讀學校 Smithers Secondary

作者姓名 Kiri Daust

# Abstract

## Purpose

Every fall, I collect highbush cranberries (*Viburnum edule*) to make jelly. In 2012, for the first time, I observed highbush cranberry leaves covered in striking patterns of raised purple dots (telia) caused by the pathogenic rust fungus *Puccinia linkii*. I investigated the distribution and effects of this rust for several reasons: little is known about *P. linkii*, highbush cranberries are an important food source for wildlife and people, and foliar pathogens may increase with climate change in sub-boreal forests. First, I investigated the patterns of telia within plants. Second, I compared the variation in infection severity among plants, hypothesising that younger plants, those in dense populations, and those in low-elevation riparian areas would be most infected. Finally, I studied the effects of *P. linkii* on its host, hypothesising that highly infected plants would produce fewer berries and produce berries with less sugar, and that infected leaves would die sooner.

## Procedures

This study investigated *P. linkii* in mixed coniferous-deciduous forest sites near Smithers, British Columbia. I marked a total of 41 randomly-selected focal *V. edule* plants in four sites. To examine within-plant patterns of infection, I photographed four leaves of each plant and used a graphic analysis program to examine the size, density and coverage of telia. To assess among-plant patterns, I compared infection severity (5 classes of telia coverage), to three ecological variables: host density within 5m, position on a moisture gradient, and plant maturity. To investigate the effects of *P. linkii* on its host, I compared infection severity to the number of berries produced, the proportion of

malformed and infected berries, and the sugar content of mature berries as measured with a handheld refractometer. I measured leaf mortality in fall.

## Results

*P. linkii* produced a characteristic pattern within each plant: higher leaves consistently had fewer but bigger telia than lower leaves. Across sites, plants were significantly more infected in areas of high host density. Within sites, young plants and plants in moister ecosystems were significantly more infected (increases of  $1.1 \pm 0.2$ ;  $F_{1,128}=44.8$ ,  $P<0.001$  and  $1.7 \pm 0.5$ ;  $F_{1,145}=95.9$ ,

$P<0.001$  severity classes respectively). There was no relationship between infection severity and the total number of berries produced. However, highly infected plants produced 20 times more malformed and infected berries than plants with low infection severity. In addition, plants with higher levels of infection produced berries with about 15% less sugar ( $F_{1,63} = 19.4$ ,  $P<0.001$ ). Highly infected leaves had significantly more area of dead tissue ( $F_{1,97} = 21.5$ ,  $P<0.001$ ).

## Conclusions

Although the long-term effects of *P. linkii* on *V. edule* are unknown, this study suggests that the pathogen stresses plants. Climate change is projected to lead to moister springs in the study area, potentially increasing infection severity. Increased infection may reduce berry quantity and quality, potentially reducing food availability for over-wintering birds and small mammals, fall food for bears, and jelly for people.

## INTRODUCTION:

Last summer, I noticed that highbush cranberry (*Viburnum edule*) bushes in the forests near our house had striking patterns of raised dark-purple dots on their leaves. I collected samples of the dots and learned that they are reproductive structures (telia) of the rust *Puccinia linkii* (B. Callan pers comm).

Almost nothing is known about *P. linkii* (A. Woods pers comm, B. Callan pers comm, Kavak 2004). Besides being interested in the patterns of telia, I thought that learning about the effects on *V. edule* would be useful because infection may increase with climate change (A. Woods pers comm.) and the berries are a valuable food for wild animals and humans.

I investigated three aspects of *P. linkii*: the distribution of telia within plants, the distribution of infection among plants, and the effects *P. linkii* has on *V. edule*.

## PART 1: DISTRIBUTION WITHIN PLANTS

### Introduction:

I noticed that *P. linkii* telia formed a fascinating pattern within each plant: the top leaves had few dots that were all large; dots were smaller and more plentiful on lower leaves (Figure 1). I wanted to confirm these observations, and determine likely hypotheses.



Figure 1. Photograph of three leaves from same plant (first, third and sixth row down) showing pattern in distribution of telia.

### Methods:

I photographed the top leaf, third leaf, middle leaf and bottom leaf (on a grid for scale) of 10-11 randomly-selected focal *V. edule* plants in each of four sites (164 leaves total). I used a graphic analysis program to determine mean size and density of telia per leaf. I visited sites weekly to monitor telia growth.

### Results:

Telia did not change size or shape after the initial measurement in mid-August. Within plants, higher leaves had fewer and bigger telia than lower leaves (Figure 2; density:  $F_{1, 145} = 26.6$ ,  $P < 0.001$ ; size:  $F_{1, 102} = 37.6$ ,  $P < 0.001$ ; GLM blocked by site and plant). The size pattern was less apparent in the two sites with lower infection overall.

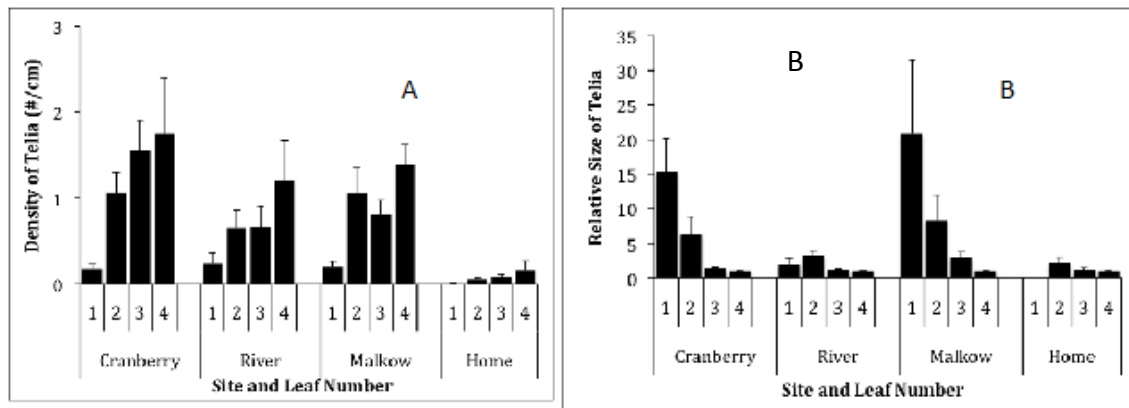


Figure 2. Patterns in density (A) and size (B) of telia with leaf position (1=highest leaf) in four sites (Mean and SE).

Telia within a leaf were similar in size, except for a few plants in one site where there were two distinct size classes.

### Discussion: Plants had bigger and fewer spots on higher leaves.

I listed hypotheses for this pattern, and considered evidence for each. I was unable to test hypotheses in this preliminary study, but could infer likelihood (Platt 1964). The most consistent hypotheses are that overwintering teliospores are dispersed from the ground, so that more spores land on lower leaves, and that higher photosynthetic rates in top leaves allow telia to grow larger. These hypotheses require a single infection event. Most leaf pathogens require specific weather conditions (Vallavieille-Pope et al 1995, Woods et al 2005); hence, this does not seem improbable.

## PART 2: DISTRIBUTION AMONG PLANTS

### Introduction:

Infection severity varied among plants. Severity should be a function of: 1) the probability of a spore landing on a leaf, 2) the probability of the landed spore infecting the leaf, and 3) the growth rate of the fungus in the leaf. 1) If no spores land, leaves cannot become infected. There should be more spores in area of high host density. 2) Spores need a moist environment to infect successfully (Vallavieille-Pope et al 1995). It is moister in low elevations riparian areas. 3) To grow, the fungus needs energy; young plants photosynthesise more (Wolf 1993, Kitajima et al 2002). Hence, I examined infection severity in relation to 1) host density, 2) environment and 3) plant age.

### Methods:

To look at density, I estimated percent cover and counted the number of *V. edule* plants in a 5-m area around each plant used in Part 1. I compared infection severity to density class. To look at the effects of environment, I ran four transects up cranberry-covered hills from riparian areas and compared infection severity along transects. To examine the effect of plant age, I compared age and infection in four sites (133 plants). To control for environmental variables, I also compared infection severity of the 41 plants from Part 1 to the severity of their neighbours.

### Results:

Infection severity was higher where host density was higher (Figure 3A;  $F_{1,39}=15.8$ ,  $P<0.001$ ; sites combined).

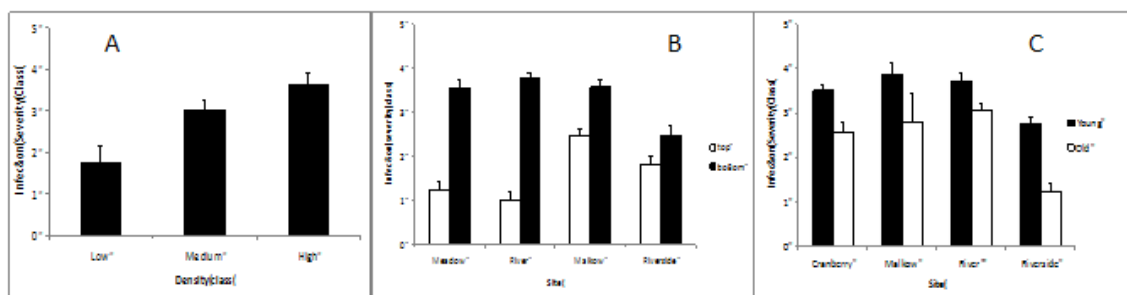


Figure 3. Effect of plant density (A), environment (location on transect) (B), and plant age (C) on infection severity (Mean and SE).

Plants were more infected in riparian areas at the bottom of transects (Figure 3B;  $F_{1,145}=95.9$ ,  $P<0.001$ ). Young plants were more infected than old plants (Figure 3C;  $F_{1,128}=44.8$ ,  $P<0.001$ ).

**Discussion:**

Infection was higher in sites with higher host density, consistent with other research (Gilbert 2002).

**Plants were more infected in low riparian areas.** The higher moisture at the bottom of transects could increase the probability of infection (Vallavieille-Pope et al 1995). If climate change leads to wetter springs as projected, infection severity may increase, similar to the pattern Woods et al. (2005) found with *Dothistroma* needle blight.

**Young plants were more infected.** Younger plants photosynthesise more (Kitajima et al 2002), and the rust may take advantage of the extra sugar. Alternatively or additionally, because young plants are generally shorter, more spores may land on leaves.



## PART 3: EFFECT ON PLANT

### Introduction:

*Viburnum edule* berries are an important source of food for bears, overwintering birds and small mammals, and people. First Nations people have valued them for years.

Little is known about the effects of rusts on wild plants (Paul and Ayers 1987). Because of *V. edule*'s important ecological role, I wondered if *P. linkii* harmed the plants. I looked at berry production, sugar content, and leaf aging.

### Methods:

I counted berries on focal plants in August and September and compared numbers to infection severity. I collected berries from 68 plants with different infection severities in three sites, extracted the juice, and measured the sugar content using a spectrometer. I compared mean sugar per plant with infection severity. I measured leaf colour change (red and brown) and compared colour change to infection severity measured as the proportion of each leaf infected.

### Results:

There was no pattern between infection severity and number of berries; however, highly infected plants had about 20 times as many undeveloped or infected berries (MWU=0,  $P=0.05$ ).

Plants with higher infection produced berries with less sugar (Figure 4;  $F_{1,63}=19.4$ ,  $P<0.001$ ).

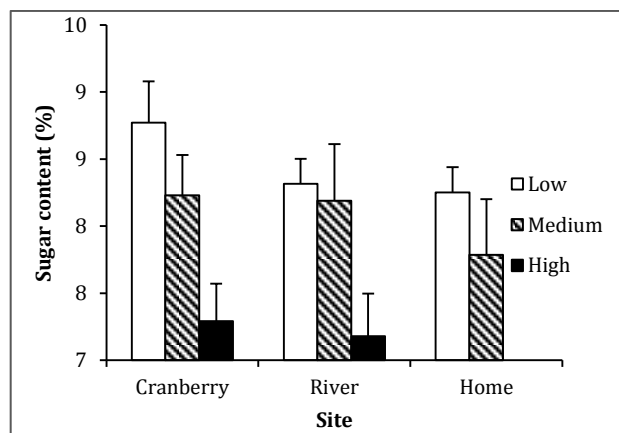


Figure 4. Percent sugar in berries from plants with different infection severities (three sites; Mean and SE)

Leaves of highly infected plants were browner sooner ( $F_{1,97} = 21.5$ ,  $P<0.001$ ).

**Discussion:**

**Highly infected plants produced less-sweet berries and leaves turned brown sooner**, likely because the fungus reduces the plants' available energy by reducing photosynthetic area and by taking supplies from the plant (Inglese and Paul, 2006).

## CONCLUSIONS

This is the first study that has examined *Puccinia linkii* in the wild. Part 1 found that telia were bigger and fewer on higher leaves. Part 2 found that infection varied with density, elevation and plant age. Part 3 documented negative effects of the pathogen; it showed that highly infected plants have less-sweet berries and turn brown sooner. My study was observational; therefore results suggest rather than test hypotheses. The long-term effects of *P. linkii* on *V. edule* are unknown. However, my study suggests that the pathogen may stress plants, especially if severity increases with moister springs as projected with climate change, potentially reducing food available to ecosystems and people.

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## 評語

A concise work in describing systematically the distribution and effects of *Puccinia linkii* on Cranberry. Good job!