Impact of the Rust *Puccinia linkii* on Highbush Cranberry, *Viburnum edule,* near Smithers, British Columbia

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The berries of Highbush Cranberry (*Viburnum edule*) are an important food source for wildlife and for people in rural areas. In 2012 and 2013, many Highbush Cranberry plants in northwestern British Columbia were unusually severely infected by the rust *Puccinia linkii*, with telia covering up to half of each leaf. Given the ecological importance of the overwintering berries, I studied the impact of the infection on the production and quality of berries in mixed forests near Smithers, British Columbia. Sites where Highbush Cranberry bushes were infected with the rust had significantly more undeveloped berries. Plants from sites with higher levels of infection produced berries with significantly less sugar. Dead leaf tissue was also significantly more prevalent in infected plants. This study provides evidence that *Puccinia linkii* may stress plants, leading to reduced quality and quantity of berries, especially if the severity of the infection increases with the increasingly moist springs that are projected for the region.

Key Words: *Puccinia linkii*; *Viburnum edule*; Highbush Cranberry; rust; foliar pathogen; berry sweetness; effects of rust; British Columbia

Introduction

In the summer of 2012, Highbush Cranberry (*Viburnum edule*) (also known as Squashberry) bushes in sites near Smithers, British Columbia, had striking patterns of raised dark purple dots on their leaves formed by telia of the rust *Puccinia linkii* (Figure 1). This infection had not been noticeable in the area for at least a decade (personal observation, A. Woods, personal communication). The severity of the infection varied among sites and among plants: on some Highbush Cranberries, over 50% of each leaf was covered with telia; on others, there were only a few telia on a single leaf.

Highbush Cranberry bushes produce clusters of overwintering tart red berries that are high in vitamin C and antioxidants. They are an important food for animals (Pojar and MacKinnon 1994) (personal observation) and an important traditional food source for many First Nations people (MacKinnon *et al.* 2009; Dinstel and Johnson 2011). Many people living in rural areas make jelly from the berries.

Puccinia linkii is an autoecious rust that parasitizes *V. edule* in British Columbia (B. Callan, personal communication) (Kavak 2004). Herbarium records indicate the rust has a northern North American distribution (Farr and Rossman 2013). It has also been reported from Turkey (Kavak 2004). Specimens have been collected in most Canadian provinces on a small number of *Viburnum* spp. (Farr and Rossman 2013). Teliospores overwinter on the ground and are dispersed by the wind in spring. Very little is known about the impacts of *P. linkii* (Kavak 2004) (A. Woods, personal communication) (B. Callan, personal communication).

Puccinia linkii may have potential implications for food production, and foliage diseases may increase with climate change in sub-boreal forests (Woods *et al*. 2005) (A. Woods, personal communication). I hypothesized that highly infected *V. edule* plants would produce fewer berries, would lose berries before maturity, and would produce less-sweet berries because *P. linkii* would reduce the amount of photosynthetic area on the leaves and absorb energy, leaving less for reproduction. I also hypothesized that rust would stress leaves and that highly infected leaves would die sooner.

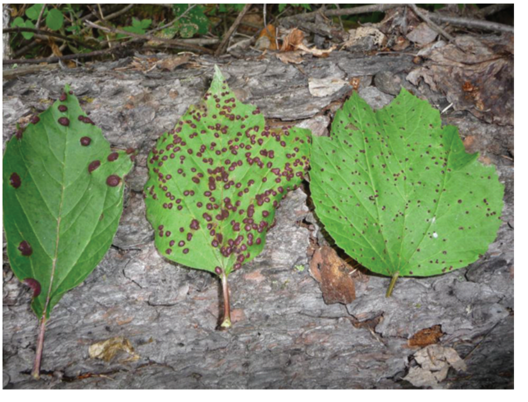

FIGURE 1. Three leaves collected on 13 August 2012 from the same Highbush Cranberry (*Viburnum edule*) plant near Smithers, British Columbia (*left to right*, from the first, third, and sixth row down) showing pattern in distribution of telia of the rust *Puccinia linkii*. Photo: Karen Price.

Methods and Study Area

This study investigated *Puccinia linkii* in four moist, rich mixed coniferous–deciduous forests in the dry, cool Sub-Boreal Spruce biogeoclimatic subzone (SBSdk) (Banner *et al*. 1993) near Smithers, British Columbia. The four sites are identified as Home (54°39'01"N, 127°07'21"W), Cranberry (54°39'26"N, 127°07'55"W), River (54°39'45"N, 127°07'44"W), and Malkow (54°49'08"N, 127°06'21"W). Three sites (Home, Cranberry and River) were located on floodplains in the

SBSdk/08 biogeoclimatic site series and Malkow was on an SBSdk/06 hillside.

I marked 10 randomly selected *Viburnum edule* plants in each of Home, Cranberry and River sites, and 11 plants in Malkow (41 plants total) and used these focal plants to quantify the severity of the *P. linkii* infection, determine berry loss, determine the quality of the berries, test the sugar content of the berries, and quantify leaf mortality.

On 13 August 2012, I photographed the top leaf, third leaf, middle leaf, and bottom leaf (*in situ*, placed on a grid for scale) of each focal plant and used a graphic analysis program (ImageJ 1.44o, Rasband, 2013) to determine the size, density, and coverage of telia per leaf. I counted the total number of berries on focal plants twice, once on 13 August 2012 when they were starting to ripen and again on 25 September 2012 at the end of the season. Not all bushes produced berries.

A local jelly-maker collected baskets of berries from Highbush Cranberries from sites with high and low rust infection on 2 October 2012 using her standard picking methods, which include picking clusters of berries and removing unformed or diseased berries later. After the berries had been sorted, I counted the berries rejected by the jelly-maker in three high-infection and three low-infection samples and used a Mann-Whitney *U* test to determine the significance of the differences between the high- and the low-infection samples.

To determine the sugar content of fully formed mature berries and correlate it to infection severity, I collected three ripe berries from each of 68 plants (including from the focal plants and from additional randomly selected berry-producing plants) with different infection severities in three sites on 25 September 2012. Severity classes (low, moderate, and high) were based on the coverage and distribution of telia on each plant. If plants had more than one berry cluster, I collected berries from different clusters.

I pricked and squeezed each berry to extract a drop of juice, and I measured the sugar content (Brix) using a hand-held refractometer (Model RHW-25, Lee Valley Tools, Ottawa, Ontario). I determined the correlation between the mean sugar percentage per plant and the infection severity and I used a general linear model blocked by site for analysis.

To determine leaf mortality, I measured the percentage of each leaf that was brown weekly as leaves changed colour between 30 August and 25 September on the focal plants at three sites (Home, Cranberry and River). I determined the correlation between the colour change and infection severity (telia coverage determined above), and I used a general linear model blocked by site and plant for analysis.

To better understand historical patterns of infection, I searched the online herbaria databases of the Pacific Forestry Centre, the University of British Columbia, the U.S. Department of Agriculture, and Purdue University for records of *Puccinia linkii* from British Columbia, and I examined climate records (Environment Canada 2013) for the collection sites and dates.

A voucher specimen of *P. linkii* for this study has been deposited at the National Collection of Fungi on the Central Experimental Farm in Ottawa with the following number: DAOM 242721.

Results

Analysis showed that there was no correlation between the severity of the *Puccinia linkii* infection and the number of berries initially produced by the Highbush Cranberry plants.

It was not possible to detect any patterns in the number of berries lost during ripening, as many animals ate the berries from the plants selected (evidenced by piles of seeds and skins).

Berries collected to make jelly from plants in areas of high infection had 20 times more infected berries, with dark, hard patches, or undeveloped berries than berries collected from plants in areas of low infection. The mean percentage of rejected berries and standard error collected from plants in areas of high infection was 20.3% ± 1.9 and in the low infection samples was 1.3% ± 0.2. The differences were significant (Mann-Whitney *U* test: $P = 0.05$). Plants with higher levels of infection produced berries with less sugar (Figure 2) ($F_{1, 63} = 19.4$, $P < 0.001$). These results were consistent among sites.

Dead tissue (brown colour) was higher on highly infected leaves ($F_{1,97} = 21.5$, P < 0.001), while less

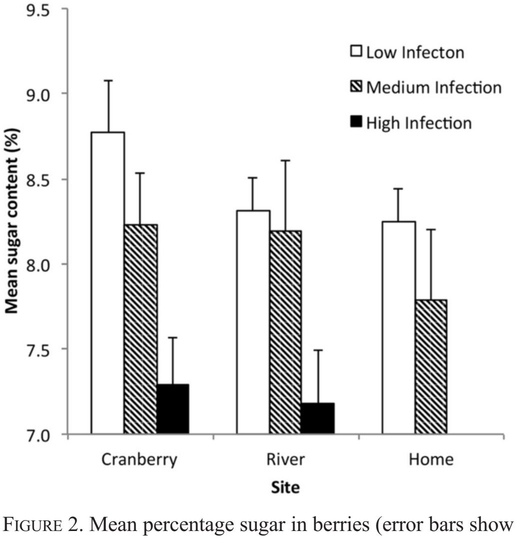

FIGURE 2. Mean percentage sugar in berries (error bars show standard error) collected on 25 September 2012 from 68 Highbush Cranberry (*Viburnum edule*) plants with different infection severities of the rust *Puccinia linkii* near Smithers, British Columbia (30 plants from the Cranberry site, 27 plants from the River site, and 11 plants from the Home site). Home site did not contain any plants with high infection severity.

infected leaves were mostly red (the expected colour in the fall).

Discussion

Viburnum edule plants that were highly infected produced more infected or unformed berries. The fully formed berries that these plants did produce had lower sugar content. This is probably because the rust reduces the plants' available energy by reducing photosynthetic area and by taking supplies from the plant (Inglese and Paul 2006) (rusts can cause plants to transport carbohydrates and minerals to infected sites (Littlefield 1981)). The fact that infected leaves turned browner sooner is consistent with stress to leaves.

Casual observations in the summer of 2013, the year following the study, indicate that the severity of the infection increased considerably in the area around Smithers and that *Puccinia linkii* has become more widespread. In addition, most bushes in 2013 had very few berries (possibly a result of reduced health during the previous season).

Other studies have documented the effects of native pathogens on hosts, with similar results. A rust (*Septoria albopunctata*) of the leaves of Premier rabbiteye blueberry (a cultivar of *Vaccinium virgatum*) had a major effect: fewer flowers germinated, leaves fell off sooner, and the following year's yield was reduced (Ojiambo *et al*. 2007). *Puccinia lagenophorae* reduced the quantity of flowers of Groundsel (*Senecio vulgaris*) (also known as Common Ragwort) by 46%, and the plants showed signs of age sooner (Paul and Ayres 1987).

Impacts on foragers have also been documented, for example, autumnal moth larvae (*Epirrita autumnata*) eating infected mountain birch (*Betula pubescens*) leaves were smaller than those eating healthy leaves (Lappalainen *et al*. 1995).

I was unable to find studies documenting impacts of rust on sugar content, although the link between rust and reduced sugar content of fruits appears in brochures (e.g., Buchner 2012).

The effect of foliar pathogens varies from killing the plant to an almost commensalistic relationship with little observable impact on the host (Jarosz and Davelos 1995). Because pathogens usually reduce the ability of a plant to produce fruit, they have the least effect when their host can reproduce without producing seeds, such as by rhizomes (Jarosz and Davelos 1995). *Viburnum edule* can spread via rhizomes; over the long term, the effect of *Puccinia linkii* on the population is unknown, but it may have an effect on wildlife that depends on fruit.

Most leaf pathogens require specific weather conditions in order to germinate (Vallavieille-Pope *et al.* 1995). *Puccinia linkii* may thrive in wet springs, a condition that is predicted to increase in this area with climate change (Pacific Climate Impacts Consortium 2013). Woods *et al*. (2005) found an increase of the *Dothistroma* needle blight with wetter summers likely related to climate change. Leaf rusts may be an indicator of increasingly wet conditions (Woods *et al*. 2005).

A search for collections of *P. linkii* in herbaria to look for patterns between wet springs and infection was inconclusive. There are at least eight collections of *P. linkii* from British Columbia, three of them from 1954. Climate records for this area (Environment Canada 2013) show that May 1954 was unusually wet; the first record of *P. linkii* in this area, in 1951, also coincided with a wet May. While there are not enough data to confirm a correlation with wet springs, these observations are consistent with this hypothesis.

This study provides evidence that *Puccinia linkii* may increasingly stress plants, leading to reduced quality and quantity of berries, especially if the severity of the infection increases with the moister springs that are projected for the region.

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