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Factors Influencing the Distribution of *Bignonia capreolata* (Carl Linnaeus 1753) in Western North Carolina

Justin Tapia
Environmental Science Department
The University of North Carolina at Asheville
One University Heights
Asheville, North Carolina 28804 USA

Faculty Mentor: Dr. Irene Rossell

Abstract

The Hot Springs Window is a geologic area in Madison County, NC, that supports many rare and uncommon plant species. This is due to the area's unique geology that has exposed rocks millions of years old which, as they erode, have affected the composition of the surrounding soil. Crossvine (*Bignonia capreolata*) is a woody evergreen vine that occurs throughout the southeastern United States, but its range is discontinuous in western North Carolina. Within the Hot Springs Geologic Window, however, there is a relatively large population. This study seeks to investigate the reason for this distribution by examining habitat characteristics and analyzing soils within several areas of Western North Carolina where Crossvine is known to thrive. Locations include two sites in the Hot Springs Window of Madison County and one in Graham County. Surrounding habitat data were collected from a total of 48 Crossvine plants, and soil was collected for each plant. Soil samples were analyzed at Water's Agricultural Laboratory in Warsaw, NC. Results confirmed that Crossvine occurs at low elevation sites and revealed a preference for higher concentrations of Mg and P in surrounding soils, evidenced by the higher vine density at Paint Rock site over the other two sites. Overall, Crossvine is a generalist species that tolerates a range of soil conditions and host species. The relationship between population density and Mg and P soil nutrients should be further explored by controlling for elevation as a variable.

Introduction

Crossvine (*Bignonia capreolata*, Carl Linnaeus 1753) is a native woody evergreen vine considered to be common across much of the southeastern United States (Manning, 2000). Its range extends from Texas eastward to the Atlantic Coast and from Florida northward to Illinois and Ohio. The vine has been documented to grow to lengths of up to ~24.4 meters and can achieve a basal diameter of ~15.2 cm (Weeks and Harmon, 2012). Crossvine has adhesive tendrils that allow it to scale vertical surfaces, such as trees and rocks, to access higher light exposure (Leicht-Young, 2014). While Crossvine is known to climb trees, it is not known to damage them (Leicht-Young, 2014). Crossvine prefers full sun and moist, well-drained soils, although it is also considered drought-tolerant and is relatively adaptable to a range of environmental conditions (USDA, 2024). Crossvine is unique in western North Carolina, as it is the only high-climbing evergreen woody vine that is native to the mountains. Other native high-climbing vines such as Poison Ivy (*Toxicodendron radicans*, Carl Linnaeus 1753), Virginia Creeper (*Parthenocissus quinquefolia*, Carl Linnaeus 1753), Wild Grape (*Vitis rotundifolia*, Sir Walter Raleigh 1584), and Pipevine (*Aristolochia macrophylla*, Lamarck 1783) are deciduous, and other evergreen vines such as English Ivy (*Hedera helix*, Carl Linnaeus 1753) are exotic invasives.

Weeks and Weeks (2012) provided examples of the ecological benefits of Crossvine, such as year-round habitat for Cardinals, Catbirds, and Grey Squirrels, due to its evergreen foliage. Crossvine is also an important food source for Hummingbirds, as its relatively early blooms provide foraging opportunities when other nectar producing flowers are not as plentiful. Another animal that utilizes Crossvine as a primary food source is the Swamp Rabbit (*Sylvilagus aquaticus*). Fowler and Kissell (2007) reported that the presence of Swamp Rabbits could be predicted 88.3% of the time based on Crossvine density and grass cover.

Although the distribution of Crossvine extends across much of the southeastern United States, there are gaps in its range in the Appalachian region. This could be due to elevation (considered a low-elevation species) but might also be related to differences in geology and soils. One example of its discontinuous range is in western North Carolina, where Crossvine has a minimal presence in Henderson and Buncombe Counties (including low elevation areas) but is more abundant just to the north in Madison County, particularly in the geological Hot Springs Window. This is a unique area that has eroded in such a manner that the underlying layers of ancient sedimentary rocks have been exposed. According to Oakley and Rossell (2011), these rocks are primarily made up of feldspathic arenite, a type of sedimentary sandstone left behind after the closure of the ancient Iapetus Sea during the formation of Pangaea. The exposure of this layer during the formation of the Appalachian Mountains has led to soil with a high calcium content and a high pH. The Paint Rock formation within the Hot Springs Window is classified as a Montane Calcareous Cliff due to this unique geology and is considered a critically imperiled habitat in North Carolina, as well as globally rare (Oakley and Rossell, 2011). This makes the Paint Rock area of particular interest as it supports a unique plant community with some rare plant species in high densities.

Crossvine is not abundant in western North Carolina. The NC Natural Heritage Program Inventories of Significant Natural Areas in Madison (Oakley and Rossell 2011) and Graham Counties (Schwartzman 2015) were used to identify locations supporting Crossvine. In Madison County, Crossvine was reported at only four sites, all of which are situated along the French Broad River within the Hot Springs Window: (1) the xeric forest surrounding Paint Rock, (2) the Oak-Hickory forest surrounding the nearby Lover's Leap Trail, which has cliffs similar to those at Paint Rock, (3) the Chestnut Oak forest on Murray Ridge, which is close to Paint Rock and has many rocky outcrops, and (4) a forest situated along the railroad tracks across the French Broad River from Paint Rock. Initial scouting of the areas produced 198 occurrences of Crossvine, with the majority (52%) found on live trees, 30% on rock faces, 10% on snags, and 8% on the ground. In Graham County, Crossvine was reported in the Cheoah River floodplain, and we located an additional site in Madison Country (the Laurel River trail). All of these sites are at a regionally low elevation (Hot Springs is ~1300 feet elevation, while the Cheoah River and Laurel River trail are at ~1400 feet elevation). At all sites, Crossvine occurs in forested areas near large rivers, with abundant large rocks and rocky outcrops. These habitats are similar but are known to have differing plant communities implying important differences are present to some extent.

The goal of this study is to investigate the factors that influence the distribution of Crossvine throughout WNC. Factors such as DBH (cm), Host Tree species, cohabitating vines, and bark texture (smooth, scaley, rough, and exfoliating) as a means of further explaining crossvine habitat/host preferences will be collected. More importance will be placed on soil characteristics due to the abundance of the vine within the Hot Springs Geologic Window. Understanding the factors that influence the populations of our native species is a key element for managing native plant communities and understanding the bearing soils have on plant distribution.

2. Methods

2.1 Site Descriptions

Three sites, one in Graham County and two in Madison County, were sampled for this study. The Cheoah River (CR) floodplain area (Figure 1) was selected as the Graham County sampling site due to its relative ease of access, known presence of Crossvine, and distance from the Hot Springs Geologic Window. The Cheoah River site is a relatively thin strip of land between Lake Santeetlah and Lake Cheoah, flanked on both sides by relatively tall mountain faces. The elevation along the river site was approximately ~416.4 m. The plant community at this site was composed of common floodplain species, including Sycamore (*Platanus occidentalis)*, Sweet Gum (*Liquidambar styraciflua*), Tulip Poplar (*Liriodendron tulipifera*), Musclewood (*Carpinus caroliniana*), Yellow Birch (*Betula alleghaniensis*), and various Maple (*Acer*) species. The understory was composed primarily of Rhododendron *(Rhododendron spp.*) and tree seedlings, with *Acer* seedlings being the most common.

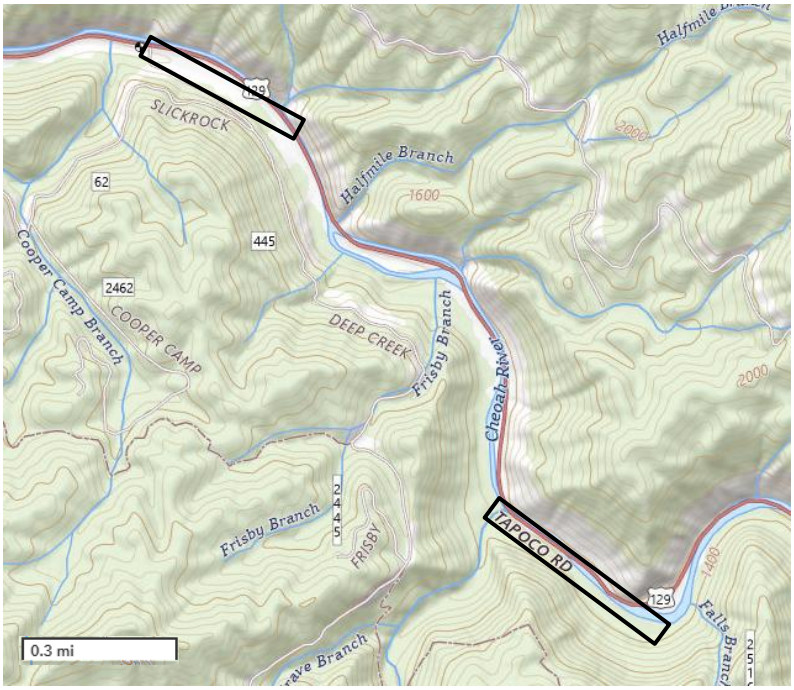


Figure 1. Map of the Cheoah River floodplain sampling area. Map generated with the USPS topo Builder Application (accessed January 22nd, 2025)

The Paint Rock (PR) area (Figure 2) in Madison County was selected for ease of access and the known presence of Crossvine. This site is of particular interest to this study as it is located within the Hot Springs Geologic Window. It consists of a floodplain surrounded by montane calcareous cliff environments and is located along a portion of the French Broad River on the border between Tennessee and North Carolina. The site elevation was ~384.0 m. The plant species at this site consisted of Eastern Hemlock (*Tsuga canadensis*), River Birch (*Betula nigra*), Muscle Wood (*Carpinus caroliniana*), Black Locust (*Robinia pseudoacacia*), Pignut Hickory (*Carya glabra*), Yellow Birch (*Betula alleghaniensis*), Sycamore (*Platanus occidentalis*), and Tulip Poplar (*Liriodendron tulipifera*). The understory at this site was variable and included areas with dense graminoid cover, others with forb cover, and bare soil.

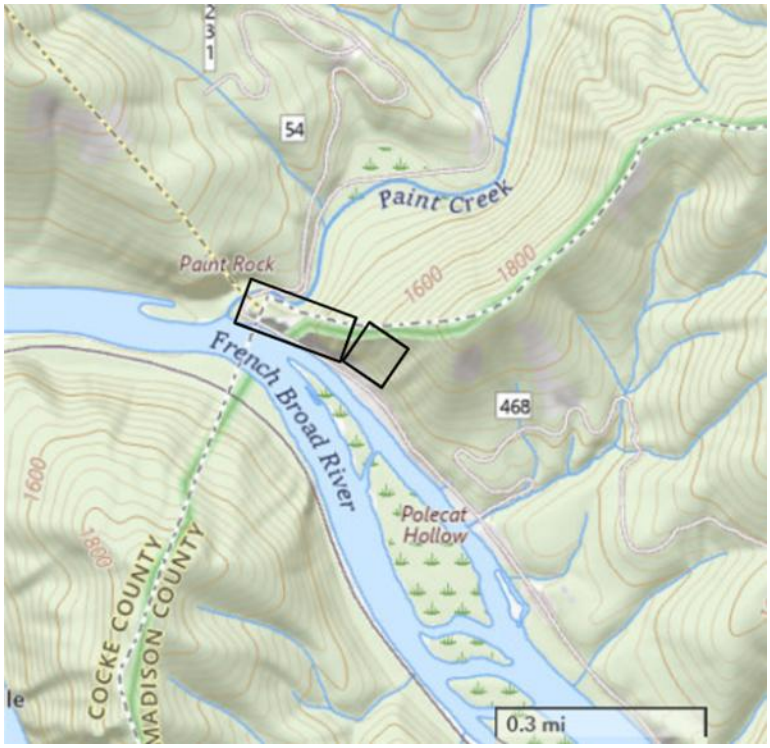


Figure 2. Map of the Paint Rock sampling area. Map generated with the USPS topo Builder Application (accessed May 4th, 2025).

The third study site was along the Laurel River (LR) trail in Madison County. This location was selected due to ease of access and the presence of Crossvine. This site is in the floodplain area following Big Laurel Creek, a tributary of the French Broad River. Site elevation averaged ~438.9 m. The dominant plant community consisted of Tulip Poplar (*Liriodendron tulipifera*), White Oak (*Quercus alba*), Musclewood (*Carpinus caroliniana*), and Carolina Silverbells (*Halesia caroliniana*) in the overstory. The understory was mostly Rhododendron *(Rhododendron* spp.) and tree seedlings, with *Liriodendron* and *Quercus* dominating.

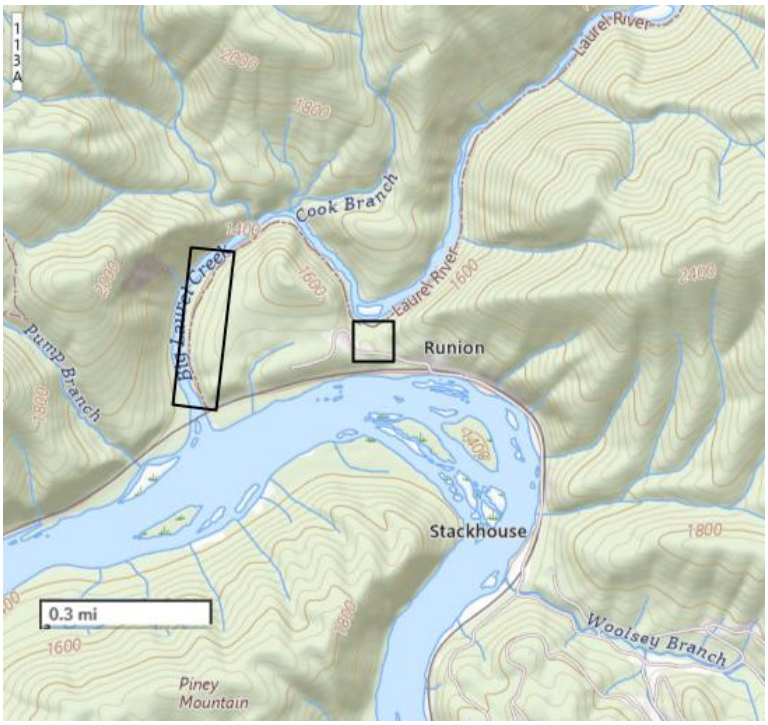


Figure 3. Map of the Laurel River trail sampling area. Map generated with the USPS topo Builder Application (accessed Jan 22, 2025).

2.2 Experimental Design

During this study, 48 Crossvine plants were selected, and 48 soil samples were collected in the area immediately adjacent to the base of the vines across the three selected sites. We selected 13 sampling points at Paint Rock, 20 at the Cheoah River, and 15 at the Laurel River trail. At each site, sampled Crossvines were selected using a random number generator (RNG) between 1-3. The result of this randomized number would determine which vines were included in the sampling. For example, if the RNG produced a 2, every second vine encountered haphazardly would be sampled from. For each plant, we recorded host tree DBH and bark texture (somewhat subjective interpretation), elevation, cohabitating vines, number of crossvine stems/tree, and slope azimuth.

2.3 Soil Collection Procedure

At each chosen vine, a 1m² quadrat was placed at the base of the vine composed of four one-meter sticks. Within the quadrat, soil core locations were chosen using a random number generator and two one-meter sticks to pick random coordinates for sampling. For each sample, two numbers, 0-100, were generated, representing the centimeters along each of the meter sticks. Ten soil cores were taken from each quadrat at a depth of ~ 10 cm to obtain a sufficient amount of soil for the soil analyses (~ 470 ml of soil).

All soil samples were taken with a stainless-steel soil corer with a diameter of 2.54 cm. This process was completed a total of 48 times totaling 480 individual soil cores. Soil samples were homogenized, air-dried, and placed in labeled plastic bags. Samples were subsequently shipped to Waters Agricultural Laboratory in Warsaw, NC, for soil analysis. The analysis included soil pH, cation exchange capacity (CEC), calcium, potassium, magnesium, phosphorus, and humic matter.

2.4 Statistical Analysis

An ANOVA test was used to compare the soil data (provided and analyzed in lbs/acre, results converted to kg/ha for table), tree DBH, site azimuth, elevation, and number of crossvine stems/tree across all three sites. Outliers were not removed from the data set as they were not found to significantly alter the p-value. Tukey's test was used to determine significant differences between descriptive variables such as bark texture, tree species, and cohabitating vines were examined with descriptive statistics. All statistical tests were performed using Microsoft Excel.

Results

Table 1. Host Tree Species Supporting Crossvine at Three Sites in Western North Carolina

Common Name	Paint Rock	Cheoah River	Laurel River
Carya glabra	23	-	7
Tsuga canadensis	15	-	-
Betula nigra	15	-	-
Carpinus caroliniana	15	15	20
Robinia pseudoacacia	8	-	-
Betula alleghaniensis	8	15	-
Platanus occidentalis	8	-	7
Liriodendron tulipifera	8	30	33
Liquidambar styraciflua	-	15	-
Oxydendrum arboreum	-	10	-
Quercus falcata	-	5	-
Acer saccharum	-	5	-
Fraxinus americana	-	5	-
Quercus alba	-	-	13
Halesia carolina	-	-	13
Acer negundo	-	-	7

Species richness did not differ between the three sites (PR=8, CR=8, LR=7), but species composition did. The PR site included three species not found at other sites, the CR site contained five species not found at the other sites, and the LR site had three species not found at the other sites.

Table 2. Comparison of Host Tree Bark Textures Across Sites

	Paint Rock	Cheoah River	Laurel River	All Sites
Smooth (%)	0	20	20	12
Scaley (%)	31	20	7	24
Exfoliating (%)	15	15	7	15
Rough (%)	54	45	66.7	48

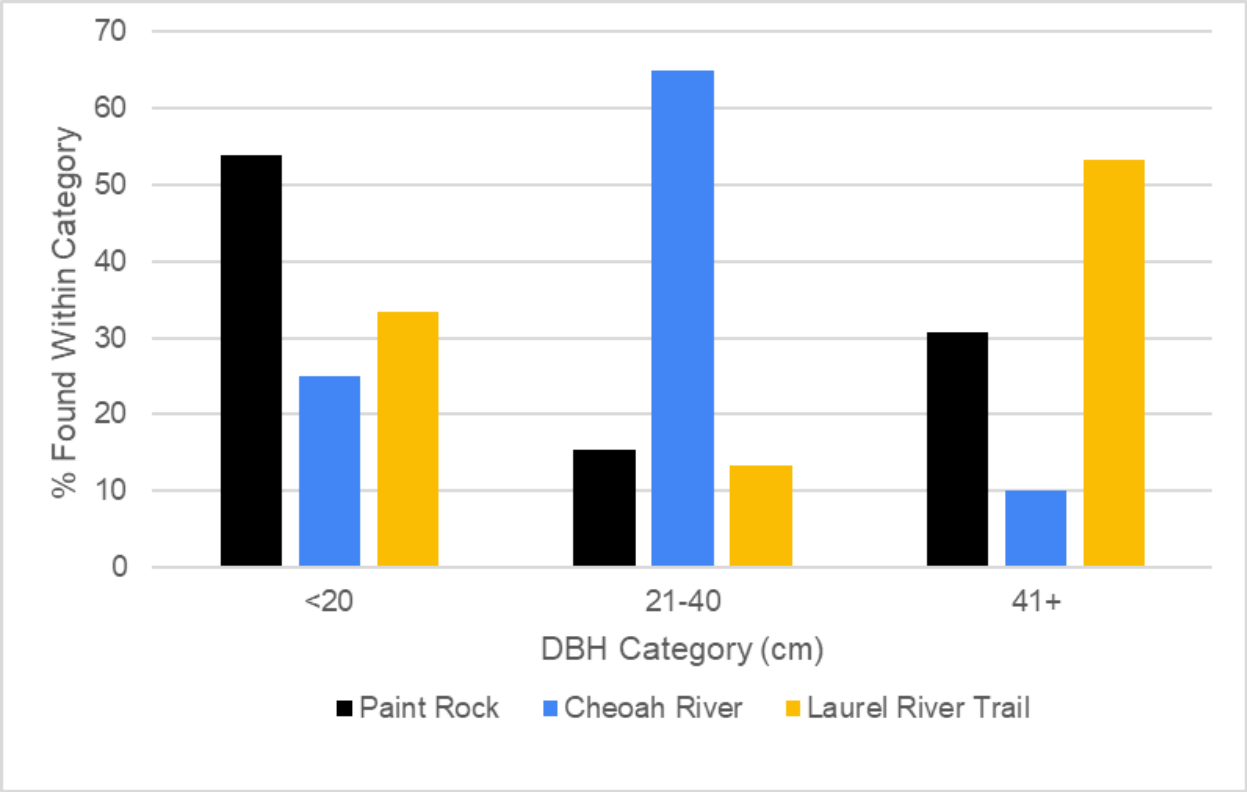
Percent occurrence of Crossvine on a given bark texture was highest across all sites at 48% rough and lowest at 12% for smooth textures. Scaley texture was the second most common bark texture that crossvine was found to occur on at 24% across all sites. PR was the only location at which a smooth textured host was never sampled.

Table 3. Summary of Cohabitating Vines Across Sampled Sites

	Paint Rock	Cheoah River	Laurel River	All Sites
VA Creeper (%)	-	5	-	2
Poison Ivy (%)	46	-	7	15
Bittersweet (%)	8	-	-	4
Kudzu (%)	-	10	-	4
None (%)	46	85	93	77

Across all sites Crossvine occurred on host trees alone the majority of the time (77%). The PR site was the only one in which Crossvine occurred just as often as not with another vine (Poison Ivy). Virginia creeper was found to co-occur the least with 2% across all sites.

Figure 4. Percentage of Host Trees in DBH Categories at Each Site



The size of host trees varied greatly among sites. This figure was composed for visual comparison. The PR site had mostly small host trees (<20cm DBH), the CR site had mostly medium-sized trees (21-40cm DBH), and the LR site had mostly large trees (41+cm DBH). This variation in stand structure indicated a wide array of host tree sizes. The Tukey's test between sites for the mean DBH (cm) between sites revealed a significant difference (CR<LR).

Table 4. Habitat and Soil Characteristics at Each Site

Variable	PR	CR	LR	P-value	Tukey Test Results
Elevation (m)	385.9	416.5	439.1	<0.001	PR<CR<LR
Azimuth (degrees)	260.6	77.9	267.7	<0.001	PR>CR, CR<LR, PR=LR
DBH (cm)	25.1	26.2	43.1	0.029	CR<LR
Stems/Tree (no.)	2.6	1.9	1.7	0.049	PR>LR
pH	6.22	5.71	5.79	0.166	
CEC	12.4	8.1	10.6	0.061	
HM	0.59	0.42	0.65	0.282	
Ca (kg/ha)	3310.8	1949.5	2590.6	0.264	
K (kg/ha)	294.9	226.1	287.0	0.295	
Mg (kg/ha)	712.5	201.1	415.7	<0.001	CR<LR<PR
P (kg/ha)	45.8	18.9	32.2	<0.001	CR<LR<PR

The only characteristics that varied significantly between sites were elevation ($P<0.001$), azimuth ($P<0.001$), host tree DBH ($P=0.029$), number of Crossvine stems/tree ($P=0.049$), Mg ($P<0.001$), and P ($P<0.001$).

Discussion

The results of our study confirmed that Crossvine is a generalist species (USDA, 2024). Host tree species richness did not differ between sites (PR=8, CR=8, and LR=7), and each site contained three or more host tree species not found at either of the other sites. This difference in dominant tree species suggests no strong preference for host tree species by Crossvine. Although Crossvine has a diverse array of potential host tree species, bark texture does appear to have some impact. More information is needed to make a claim on which bark texture is preferred. We can say, however, that within our study smooth bark was the least common bark texture that this vine was found on. This makes sense as the adhesive tendrils used by the Crossvine likely have an easier time gripping surfaces with a more abrasive texture. Crossvine occurred alone on 77% of trees. This could be due to several factors, including competition for soil nutrients, sunlight, and bark space as it has been known to do (Leicht-Young, 2014). Crossvine also did not display a strong preference for host tree size, and differences between sites may be due to stand age or some other environmental factor.

Although the difference for both elevation and azimuth across the three sites was significant ($P<0.001$), the elevation difference between sites was only ~61.0 m, and all sites had relatively low elevations. Notably, the two Madison County sites (PR and LR) had a similar slope azimuth; this was expected due to the orientation of the river corridors. The CR site in Graham County, however, was significantly different from both Madison County sites. A change in azimuth alters light regime, moisture levels, temperature, and the surrounding plant community/structure (Cantlon 1953). Elevation differences can have similar impacts on temperature, soils, and plant community structure, which is reflected in the host trees at each site (Cantlon 1953).

All of these factors highlight the capacity of Crossvine to survive in many different environments. However, the number of stems per host tree varied across sites (PR=2.6, CR=1.9, and LR = 1.7). The stems/tree data may be used as a proxy for the population density of Crossvine. If vines are present in larger clusters, this could indicate an increased presence in the area at large. This is interesting as the initial prediction was that the farther from the Hot Springs Geologic Window, the lower the population density of Crossvine would be. Although Paint Rock had the most vines per tree, the other two sites had comparable stems/tree despite their distance from each other.

The majority of the soil characteristics analyzed in this study were found to be insignificant. Variables found to be insignificantly different across the three sites were pH, Cation Exchange Capacity (CEC), Humic Matter (HM), Calcium, and Potassium. Two soil variables were found to be significantly different across sites: Magnesium and Phosphorus. Tukey's test revealed the same trend for both variables (CR<LR<PR). As site location became farther from the Hot Spring Geologic Window, the amount of Magnesium and Phosphorus decreased. This significant difference in soil nutrient content further supports Crossvine's resilience across a wide array of environmental conditions (USDA, 2024, Manning 2000).

The results of this study show that the distribution of crossvine is not limited by host tree species, tree size, slope azimuth, or most soil characteristics. Crossvine's preference for lower elevations was already established; however, its preference for higher concentrations of Mg and P in the soil provides additional context to its increased presence in the Hot Spring Geologic Window relative to surrounding areas.

The methods of this study could be improved in several areas. One is that the use of a handheld soil corer in rocky soils led to varying sample quality. Crossvine was only sampled at the base of host trees, but much of the Crossvine found during early scouting, particularly at the PR site, was found growing on exposed rock faces. Due to time constraints, plants growing on rocks were excluded from this study, but including those sites would change the soil nutrient results. A large sample size would also have helped, but it was not possible due to Tropical Storm Helene occurring during the study period. The relationship between soil Mg and P and Crossvine could be further explored. For example, sites from lower elevations with known concentrations of Mg and P in the soil would allow us to determine whether elevation is the main factor influencing Crossvine distribution.

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