THE CORRELATION BETWEEN SPRINGTIME TEMPERATURES AND FLOWERING PATTERNS OF THE BLACK CHERRY (*PRUNUS SEROTINA*) IN THE UNITED STATES

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ABSTRACT: This research paper addresses the impact of changes in temperature during the spring season on the flowering of the black cherry tree (Prunus Serotina) in the United States. Utilizing data from the National Phenology Network (NPN), specifically employing the Overall Max Temperature vs. Onset Day of the Year, Seasonal Max Method, and Accumulated Growth Degree Days (AGDD) Method, we aimed to predict the phenological impacts on flowering onset dates. Among the three methods applied, Figure 2, derived from the Seasonal Max Method, yielded the most reliable data. Our analysis revealed a noteworthy negative correlation between the onset day of black cherry trees and maximum temperature. By comparing the spring season to the rest of the year, we observed an increase in maximum temperature, leading to an earlier onset of flowering dates, as indicated by the R^2 *values. Our findings demonstrate a consistent negative correlation between temperature and the flowering of the black cherry tree. As temperatures rise, the black cherry tree exhibits an earlier onset of flowering, providing valuable insights into the phenological response of this species to changing environmental conditions.*

Introduction

The black cherry tree, scientifically identified as *Prunus Serotina*, stands out as one of the prevalent cherry species in the United States, particularly thriving in the eastern region despite its non-native status. Like all living organisms, the *Prunus Serotina* undergoes the phenomenon of phenology, a study examining how organisms transition through various seasonal stages. Plant phenology, encompassing the recurring sequence of plant developmental stages, holds significance for both plant functionality and the provision of ecosystem services, influencing biophysical and biogeochemical interactions with the climate system (Piao, 2019). Within this broader framework, the *Prunus Serotina* exhibits distinctive shifts and changes, shaped by its adaptability to different seasons. Temperature, a key environmental factor, significantly influences these phenological variations. The black cherry, like other plants, relies on temperature cues, thereby contributing to our comprehension and modeling of responses to warming trends and their ecological implications. This paper delves into the specific phenological stage of flowering, a critical aspect in the reproductive cycle of this plant.

The flowering stage represents a pivotal phase in the phenological cycle of plants sensitive to temperature variations. As stated by Jagadish et al. (2016), rising temperatures and associated climate change factors significantly impact plant fitness and events linked to its flowering phase. Investigating the influence of these environmental factors on specific flowering events, such as the time of day of anthesis and flowering duration (from germination to flowering), is imperative for understanding plant and crop adaptations to a changing climate. The

Prunus Serotina typically undergoes blooming in spring. Early spring warmth induces earlier blooming, whereas colder temperatures can result in delayed flowering (Primack, 2007). Recent decades have witnessed substantial temperature variations attributed to climate change, eliciting diverse responses from plants and impacting their phenological cycles.

A comprehensive study, encompassing 134 trees in the northeastern United States, including the black cherry tree (*Prunus Serotina*), modeled potential climate change impacts. Results underscore the likelihood of substantial transformations in northeastern U.S. forests, with certain species possibly gaining habitat while others, notably the black cherry, face a decline in suitable surroundings. One of these factors that affected the surroundings of these cherries was temperature. Understanding the intricate relationship between temperature and climate is crucial. Research discerning the preferences of black cherry subspecies in specific climatic conditions correlates climate parameters with 17 morphological characteristics, revealing climate change's potential impact on black cherry distribution (Guzmán & Fresnedo-Ramírez, 2018). These findings underscore the role of climate factors, particularly temperature and humidity, in shaping black cherry morphology.

These factors prompt a fundamental question: *How can we expect the changes in temperature during the spring season to affect the flowering of the black cherry tree (Prunus Serotina) in the United States?* This research paper aims to investigate the potential correlation between spring season temperatures and the flowering response of the black cherry tree. Our working hypothesis suggests that with increasing temperatures, there is a trend of earlier flowering of the black cherry tree across the United States during the spring. Multiple attempts to address this question have involved a thorough analysis of data from the National Phenology Network (NPN).

Materials And Methods

The data for this study was collected from the National Phenology Network (NPN), a platform that records the timing of life cycle events in plant and animal species across the United States. The focus of this study is on the full flowering and open flowers phenology of the black cherry trees (*Prunus Serotina*). The NPN provides a reliable dataset with a nationwide scope. It offers a valuable resource for investigating the impact of temperature changes during the spring season on the flowering behavior of black cherry trees.

The dataset was selected to concentrate on black cherry tree phenology within the United States. This species was chosen due to our own interests, its ecological significance, and its widespread distribution across different regions of the country. The purpose of this selection is to understand how changes in spring temperatures may influence the flowering pattern of black cherry trees. The choice of the NPN dataset is motivated by its extensive coverage and long-term records of phenological events, enabling a comprehensive analysis of black cherry tree flowering patterns over time. The NPN dataset offers standardized and consistent observations, making it well-suited for studying the impact of temperature changes on the timing of flowering events in the context of climate variability.

Three Models Related To The Temperature-Dependent Variable

Overall Max Temperature Vs. Onset Day Of The Year Method

Our objective was to assess the association between temperature and the flowering phenology phase using a linear regression model. The graph's approximation follows a linear function, $y = ax + b$, where 'y' denotes the onset days of the year, 'x' represents the observed maximum temperature, 'a' signifies the correlation coefficient, and 'b' represents the model constant. Under the hypothesis of a linear relationship, the R-square test is employed to establish the proportion of variance in the dependent variable that can be explained by the independent variable.

Season Max Temperature Method

In alignment with the previous method, we used individual seasonal maximum temperatures as independent variables for constructing our linear regression model. Consequently, we derived four sets of data, each corresponding to a specific season, resulting in the establishment of four regression lines. The application of the R-square test is important because the degree of fit between the data and the respective regression models provides insights into the model's explanatory power.

Accumulated Growing Degree Days (Agdd) Method

Accumulated Growing Degree Days (AGDD) is a concept used in phenology to quantify the accumulated heat units that have occurred over a period of time, typically measured from the beginning of the growing season or a specific starting point. Growing Degree Days are a way to estimate the heat energy available for plant growth and development. The idea behind Growing Degree Days is to calculate the daily difference between the average temperature and a base temperature, below which plant growth is limited. The formula for a single day is:

$$\text{Growing Degree Days (GDD)} = \max\left(0, \left(\frac{Tmax+Tmin}{2} - T_{base}\right)\right)$$

Where T_{max} is the maximum daily temperature, T_{min} the minimum daily temperature, and T_{base} the base temperature. The maximum function is used to ensure that negative values—which would indicate temperatures below the base temperature and are not conducive to plant growth—are treated as zero. The ADGG over a period of time is obtained by summing the daily Growing Degree Days from the beginning of the growing season. The accumulated value provides a measure of the cumulative heat exposure that the plants have experienced.

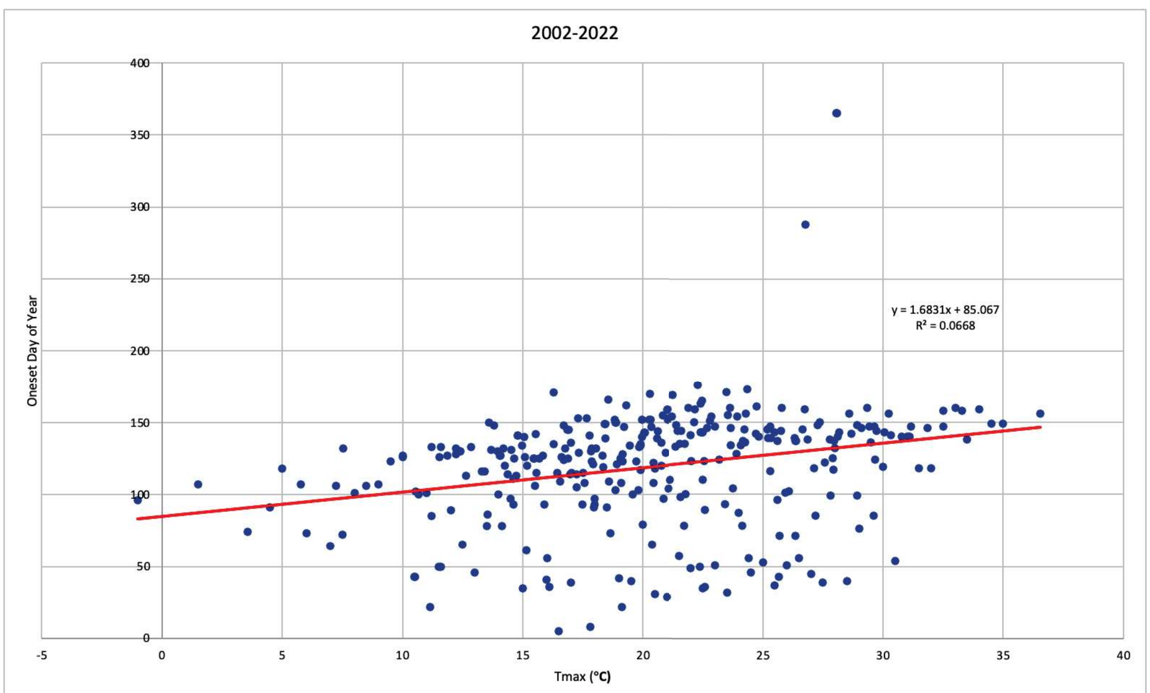

Figure 1. Linear regression graph of Overall Max Temperature and onset day of black cherry trees. The points in the graph are widely scattered, and numerous outliers are visible. Despite obtaining a positive slope value of 1.6831, statistical data fails to support its use as evidence.

Using this approach, we will set AGDD as the independent variable and build another linear regression model. The R-square test is also provided as evidence to show the results.

Data And Results

The Overall Max Temperature method has failed to provide reliable evidence to support our hypothesis that the overall max temperature is positively correlated to the onset day of black cherry trees. The linear regression analysis conducted on the collected data yielded an R^2 value of 0.0668 (**fig. 1**). This obtained R^2 value indicates a very low level of explained variance in the model. In other words, only approximately 6.68% of the variability in the flowering behavior of black cherry trees could be accounted for by the changes in temperature.

For the Season Max Temperature method, we collected data on maximum temperatures for four distinct seasons and generated a scatter plot to examine their relationship with the onset day of black cherry trees. Focusing on spring temperatures, we decided to compare the findings with the other three seasons: summer, fall, and winter. The results revealed a pattern across all seasons: a negative correlation between the onset day of black cherry trees and the max temperature. This implies that as the max temperature increases, the onset day tends to occur earlier. The strength of these correlations is quantified by the R^2 values.

For spring, the R^2 value of 0.2406 (**fig. 2**) suggests a moderate level of correlation. Similar negative correlations are observed in the other three seasons. Summer shows an R^2 value of 0.1862, fall exhibits a higher correlation with an R` value of 0.3295, and winter shows a correlation with an R^2 value of 0.1831.

All four regression lines show a negative slope which means that the maximum temperature is negatively correlated to the onset day. As the maximum temperature increases, the black cherry trees tend to have less onset days for all seasons.

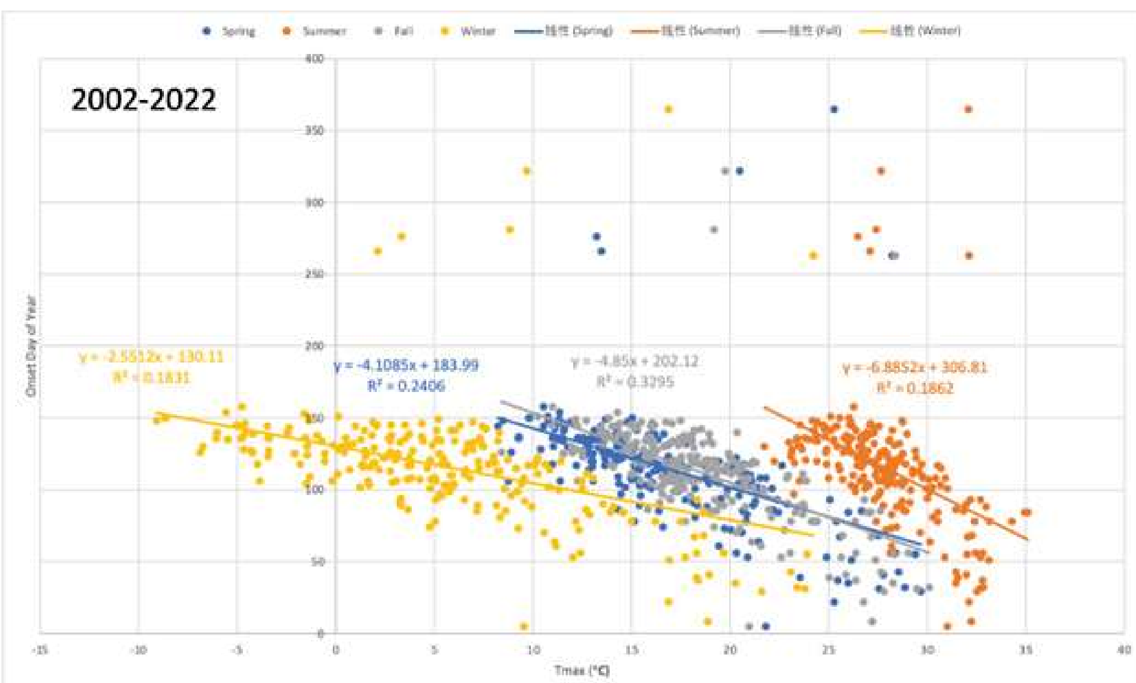

Figure 2. Seasonal Variation in Onset Day of Black Cherry Trees Relative to Maximum Temperature

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	Slope	R^2
Spring	-4.1085	0.2406
Summer	-6.8852	0.1862
Fall	-4.8500	0.3295
Winter	-2.5512	0.1831

Table 1. Summary of Statistical Data in Figure 2

In the context of our research topic of the impact of temperature on the onset day of black cherry trees, we used Accumulated Growing Degree Days (AGDD) as another approach. This model allows us to explore the cumulative effect of temperature on the timing of flowering events in black cherry trees. The regression analysis shows a significant positive correlation between AGDD and the onset day, with an R2 value of 0.3948 (fig. 3). This result indicates that the accumulation of heat is associated with a later onset day for black cherry trees. The positive correlation aligns with our expectations, considering that warmer conditions, indicated by higher AGDD, tend to delay the onset of flowering in cherry trees. However, we found that the results obtained from this perspective are deceptive. Therefore, we intend to approach it from another angle to support our hypothesis. As shown in Figures 4 and 5, we exchanged the positions of AGDD and Onset Day of Year and conducted statistical analysis on AGDD. We found that the regression curve still shows a positive correlation, with most points

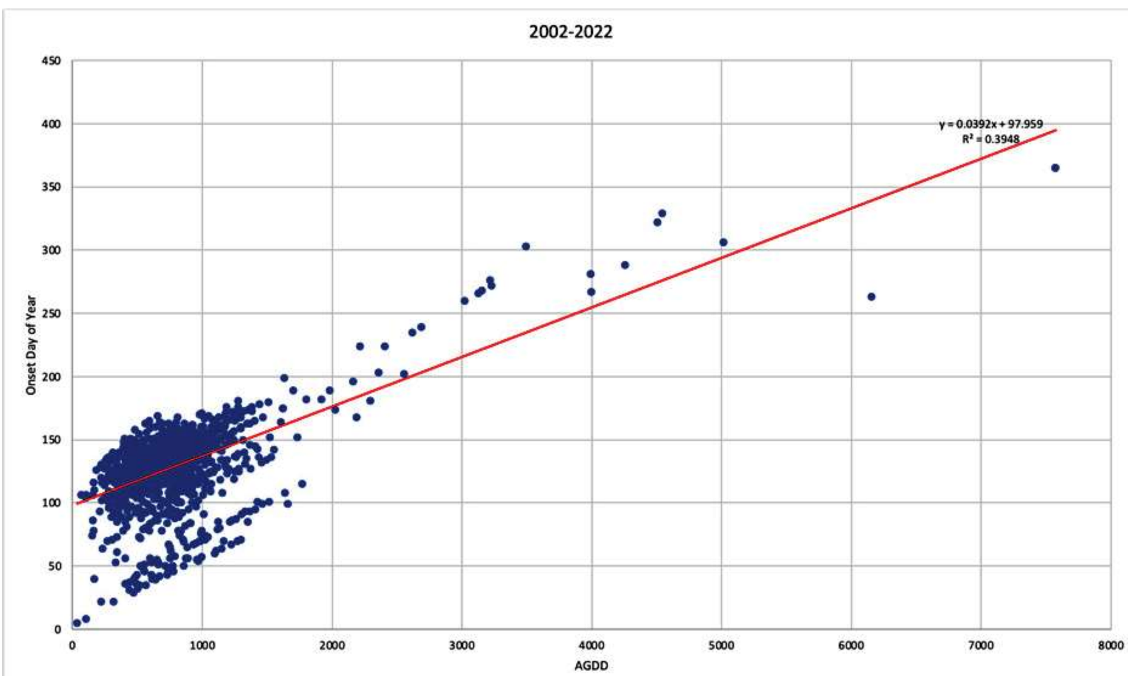

Figure 3. Influence of Accumulated Growing Degree Days on the Onset Day of Black Cherry Trees

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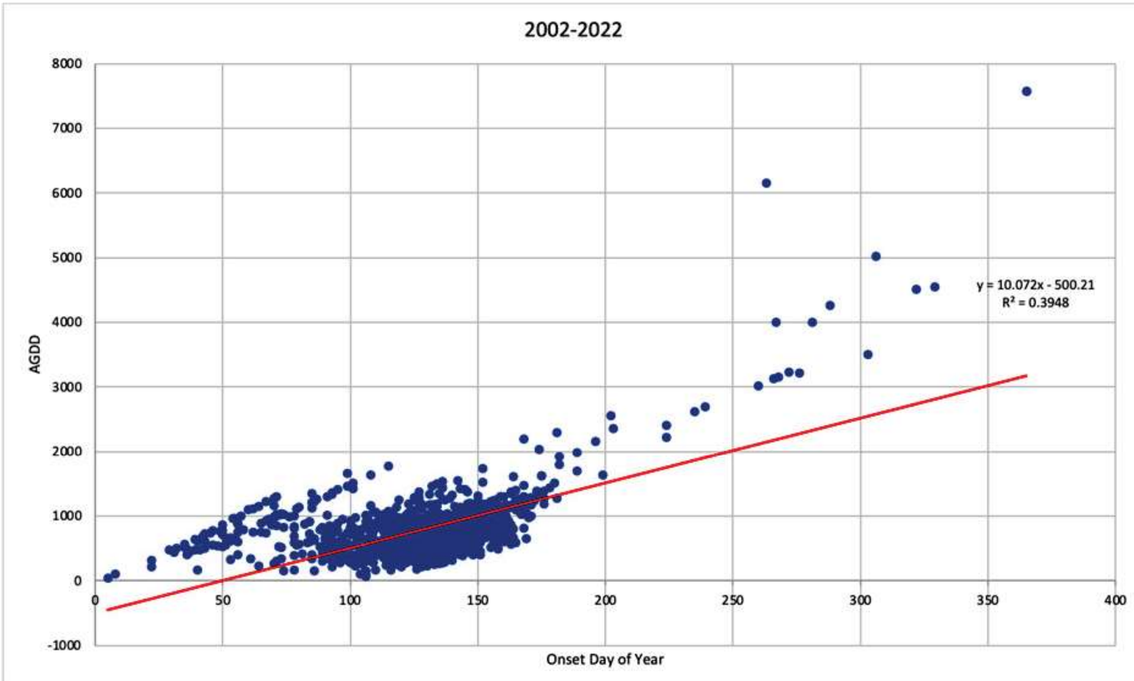

Figure 4. Correlation of Accumulated Growing Degree Days and the Onset Day of Black Cherry Trees

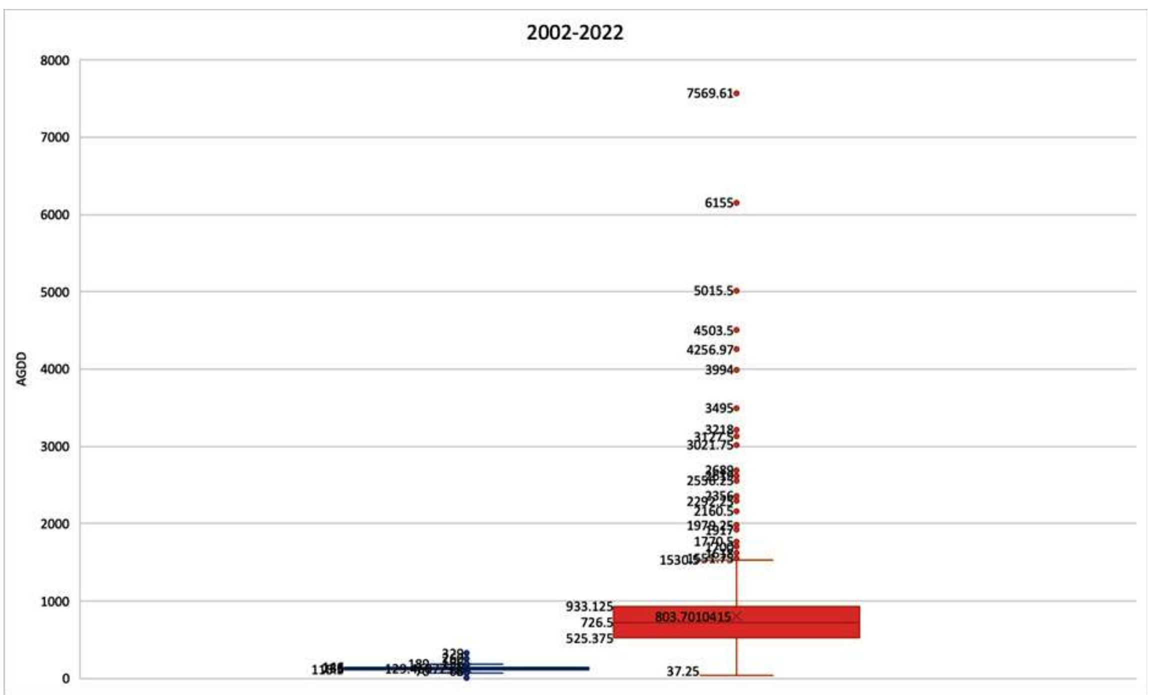

Figure 5. Statistical Analysis of the Correlation of Accumulated Growing Degree Days and the Onset Day of Black Cherry Trees

concentrated in the period from March to May. This result confirms the necessity of focusing on the spring season.

Discussion and Conclusion

Two potential explanations for the conflict of the results from the AGDD method and seasonal max temperature method (**fig. 3**) seem to be:

1. Time lag in Phenological Responses:

   The impact of temperature on the phenological events may have a time lag. While seasonal maximum temperatures provide an immediate snapshot of the weather conditions, AGDD reflects the cumulative heat over a more extended period. The onset day may respond differently to short-term temperature ups and downs (seasonal max temperatures) compared to the gradual accumulation of heat over time (AGDD).

2. Interaction with Other Environmental Factors:

   Flowering is influenced by a complex interaction of environmental factors. AGDD could capture accumulated heat but may not be able to account for other influential variables such as soil moisture and precipitation.

Nevertheless, **Figure 3** failed to validate our hypothesis. Despite obtaining a relatively high R^2 value of 0.3928, this outcome was expected given that the AGDD value is inherently time dependent. As time accumulates, AGDD is bound to increase, and consequently, a positive association with the Onset Day of the Year is expected. In light of this, we opted to reevaluate the AGDD factor from an alternative perspective.

While examining **Figure 4**, a pattern emerged with the majority of data points clustering in the 90-160 AGDD range. This clustering indicates that the flowering phenophase occurs during March to May, encompassing the spring season. The median AGDD value, calculated as 726.5 (**fig. 5**), implies that black cherry trees experience an approximate cumulative temperature exposure during spring. This finding underlines the significance of focusing on phenological data during the spring season, aligning with the direction of our research.

Reflecting on our research question: How can we expect the changes in temperature during the spring season to affect the flowering of the black cherry tree (*Prunus Serotina*) in the United States? Our findings suggest a discernible correlation between rising temperatures and earlier flowering events during the spring season. Our results indicate that an increase in temperature corresponds to a notable advancement in the timing of flowering dates, pointing towards a meaningful relationship between these variables. For our data, we analyzed three graphs:

- 3.1 (**fig. 1**) Linear Regression Graph of Overall Max Temperature and Onset Day of Black Cherry Trees
- 3.2 (**fig. 2**) Seasonal Variation in Onset Day of Black Cherry Trees Relative to Maximum Temperature
- 3.3 (**fig. 3**) Influence of Accumulated Growing Degree Days on the Onset Day of Black Cherry Trees
- 3.4 (**fig. 4**) Correlation of Accumulated Growing Degree Days and the Onset Day of Black Cherry Trees
- 3.5 (**fig. 5**) Statistical Analysis of the Correlation of Accumulated Growing Degree Days and the Onset Day of Black Cherry Trees

Figure 1 is not statistically reliable. We tested the relationship between temperature and flowering phenology phase by using a linear regression model, and from there we used the R-square test to determine the proportion of variance in the dependent variable. Our results showed that the Overall Max Temperature

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method failed to provide reliable evidence to support our hypothesis. The obtained R2 value indicated a low level of explained variance in the model; 6.68% of the variability of the flowering behavior was accounted for by changes in temperature, consequently making the data statistically unreliable. When looking at the graph you can see a positive slope but it fails to be used as supportive evidence.

Figure 2 is the most reliable evidence that was found. The data compared seasonal variation in onset day of black cherry trees relative to maximum temperature. In this data, max temperature observed in separate seasons was used to build a linear regression model. Thus, this resulted in four data sets and regression lines. Due to the focus of spring, there was a comparison established between all the seasons. The results reveal a pattern, a negative correlation between the onset day of black cherry trees and the max temperature. This implied that as the max temperature increased, the onset day tended to occur earlier. This was also shown by the R2 values.

After looking and comparing all the different graphs, we were able to conclude that there is a good correlation between the changes of temperature in the spring season with the flowering dates of the *Prunus Serotina* in the United States. This was able to stand well without our hypothesis that higher temperatures led to earlier bloom dates, which was what was discovered from the data and graphical analysis from the NPN. The results we found demonstrate that there is a negative correlation found between temperature and flowering of the black cherry tree. As the temperature increases, the black cherry tree tends to have an earlier onset of flowering dates.

Research Implications: Framing The Phenology Of Black Cherry Trees Within A Global Context

Studying the intricacies between seasonal temperatures and the phenology of plants and animals holds profound real-world implications. Our research underscores the critical importance of understanding these relationships, as we hope our work not only calls for policy changes but also inspires future research that addresses the pressing environmental challenges facing our planet.

Policy: Our investigation into the effects of changing spring temperatures on the flowering patterns of black cherry trees is not just confined to botanical curiosity; rather, it serves as a call for policy transformation. The desire for the preservation and protection of our environment rightfully urges informed decision-making, and our research provides a reason as to why. By examining connections between temperature variations and the phenology of key species, we hope to compel policymakers to develop targeted strategies for mitigating the adverse effects of climate change on all ecosystems within the United State's geographical landscape. Initiatives issued from our findings can span sustainable land management practices, biodiversity conservation, and greenhouse gas reduction. Through the lens of black cherry tree, we hope that our research advocates for policies that protect both significant abiotic and biotic factors, guarding not only the individual species but contributing to the broader preservation of entire ecosystems.

Future Research: In addition to inspiring policy changes, we hope that our paper inspires further investigation on understanding the relationship between the phenology of living species and climate change, offering solutions for pressing global challenges. In the industries of farming management, horticulture, and agriculture, the conclusions drawn from our study, coupled with subsequent research on phenological phases and environmental preservation, can revolutionize industrial practices. Farmers and agricultural stakeholders can stand to benefit significantly from a deeper understanding of how temperature fluctuations influence the phenology of their crops and farm animals. This knowledge can inform precise timing for agricultural activities such as planting and harvesting, optimizing productivity in the face of changing climate conditions.

Why you should care: With climate change altering our ecosystems, the survival of countless species, including the black cherry tree, hangs in the balance. Our research has revealed a crucial insight: as the temperature increases, the black cherry tree tends to have an earlier onset of flowering dates. Supporting evidence from a research study indicates that the potential for more extreme temperature events will ultimately impact plant productivity, and there are limited adaptation strategies for plants to cope with temperature extremes at sensitive developmental stages and warmer temperatures (Hatfield, 2015). Our study is not only an academic pursuit, but it also urges for policy change and further investigation on the topic, guiding humanity towards a sustainable coexistence with the natural world. Ultimately, the increasing climate change, the decreased productivity of plants, and other pressing environmental issues affect us directly and indirectly. These issues threaten our physical health and mental well-being, the food we consume, the clean water that is available for us to drink, the air we breathe, and the weather we experience. Given the pervasive nature of these challenges, every single person should care and express their active involvement in fostering sustainable practices, advocating for environmental policies, and contributing to the collective efforts aimed at securing a healthier and more resilient future for our planet.

Limitations And Acknowledgments

Some limitations that we faced included time limitations, knowledge limitations, and data limitations. Though we had over eight weeks to conduct our research, there was still a lot of room for improvement because of conflicts with how much data we could find using our data tools and how much knowledge we could find particularly for the background areas for this paper. It is important to recognize that there has not been a lot of research done on the specifics of temperature in relation to Prunus Serotina and that finding and digging for research that would have been easier to accomplish if there was more time.

However, given that there were limitations, we would like to acknowledge NPN, National Phenology Network, along with the Professor of this class, Caleb Trujillo, for giving us the opportunity to complete this research and guiding us throughout. We would also like to thank the Scientific Methods and Practice Class along with University of Washington Bothell for providing us access to the library's resources to allow us to find more background knowledge in this paper.

Glossary

Phenology: The study of cyclic and seasonal natural phenomena, especially in relation to climate and plant and animal life.

Prunus Serotina **(Black Cherry Tree)**: A species of cherry native to eastern North America, known for its distinctive bark and fruit. It is valued for its timber.

Onset Day: The day on which a specific phenological event, such as flowering, begins within a given year. In this study, onset day refers to the initiation of flowering in black cherry trees.

Linear Regression: A statistical method used to model the relationship between two or more variables by fitting a linear equation to observed data.

R-squared (R2) Value: A statistical measure that represents the proportion of variance in the dependent variable (e.g., onset day of flowering) that is explained by the independent variable(s) (e.g., temperature). A higher R2 value indicates a stronger relationship between the variables.

Accumulated Growing Degree Days (AGDD): A measure of accumulated heat units above a certain base temperature threshold, used to estimate the progress of plant growth and development. AGDD is calculated by summing the daily differences between the average temperature and the base temperature over a specific period, typically from the beginning of the growing season.

Slope: The steepness or incline of a line on a graph, representing the rate of change of the dependent variable (e.g., onset day) with respect to the independent variable (e.g., temperature). Positive slope indicates a positive correlation, while negative slope indicates a negative correlation between the variables.

Regression Analysis: A statistical technique used to determine the relationship between a dependent variable and one or more independent variables, often used to predict the value of the dependent variable based on the values of the independent variables. In this study, regression analysis is used to assess the relationship between temperature and black cherry tree phenology.

Correlation: A statistical measure that indicates the degree to which two variables are related or associated with each other. Positive correlation indicates that as one variable increases, the other variable also tends to increase, while negative correlation indicates that as one variable increases, the other variable tends to decrease.

Farm Management: Making and implementing of the decisions involved in organizing and operating a farm for maximum production and profit.

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