Investigating the Role of the Fibonacci Sequence Towards an Evolutionary Advantage in Plants

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Abstract

The Fibonacci sequence is a pattern commonly found in nature, especially in plants. A popular example of the Fibonacci sequence observed in nature is with lilies, which are well known for having 3 petals. The frequency of this mathematical series in nature poses a question of whether following the Fibonacci sequence plays a part in plants' survival. My general hypothesis is that the Fibonacci sequence doesn't influence survival and growth of plants. However, I am hoping to find trends supporting advantages that come with following the Fibonacci sequence. Disproving my hypothesis would lead to suggestions that following the Fibonacci sequence is linked to increased survivability rates. The Fibonacci sequence is an interesting concept that is widely studied throughout the world, but not enough research has been conducted into applying this concept on plants, specifically in terms of survival. Therefore, this paper collects evidence that can provide initial connections between plant development and displaying the Fibonacci sequence.

This hypothesis was then disproven by data comparing plants that follow the Fibonacci sequence (Fib) and those that do not (non-Fib) in three different aspects, lifespan, attraction of pollinators, and tolerance to weather. We compare specific species of plants from Fib and Non-Fib in terms of lifespan length, pollinator attraction, and tolerance to a variety of conditions. The Fibonacci sequence was said to allow plants to use their resources efficiently. This paper would support this idea by collecting data about flowers, specifically, and find out whether a mathematical concept can be applied to providing better chances of survival for flowers.

Keywords

Fibonacci, Lifespan, Cross-Pollination, Self-Pollination, Hardiness, Tolerance, Resilience, Genetic Variation, Resistance, Environment

Introduction

Concepts we gather from our speculations are often derived from patterns found in nature, such as the Fibonacci sequence. The Fibonacci sequence is an order of numbers with the following numbers being the sum of the two numbers preceding it. This was developed by Leonard of Pisa, a mathematician known as Fibonacci. He grew up in the Dark Ages in Italy and wrote many books during his time. Liber Abaci was one of, if not the most, famous works that he wrote. This text included solutions to various math problems; the solution to a rabbit regeneration problem was the sequence of Fibonacci numbers. Although unintentional, this solution introduced other mathematicians to this common principle found in nature. Thus, as this principle has been further explored by mathematicians since then, Leonard has been credited as the pioneer of this huge discovery. (1) For example, imagine you're walking into a garden when you find a pansy. Pansies usually have five petals, which follows the mathematical formula of Fibonacci numbers. Interestingly, the Fibonacci sequence is commonly found throughout nature; in fact, approximately 90% of plant species follow the Fibonacci sequence. (2) This can be found in various plant morphologies such as their number of petals, and seeds' spiral arrangements, this frequency brings to our attention an essential question: Does the Fibonacci sequence provide an evolutionary advantage to plants, specifically when applied to their flowers? Addressing this question could lead to possible solutions to increasing plants' fitness, in turn offering methods of resolving growing farming and forest issues that are occuring because of greater concentrations of carbon dioxide and warmer weather conditions brought on by climate change. (3) If plants that follow the Fibonacci sequence have greater survivability, plants that do not follow the Fibonacci sequence can be genetically altered to display signs of the Fibonacci sequence in any shape or form, such as spiral arrangements or numbers of leaves or petals. With its ability to attract more pollinators, plants that follow the Fibonacci sequence can also be focused on in future studies seeking solutions to forest issues, such as deforestation and loss of habitats, because they are able to promote interactions with pollinators within the ecosystem.

In this paper I aim to answer whether the Fibonacci sequence influences plants survival and evolutionary fitness by comparing lifespan, pollinator attraction, and tolerance to various temporal conditions in plants that follow the Fibonacci sequence in their petal number compared to ones that do not. I focus on comparing plants based on their petal numbers to have conclusive and consistent evidence on whether a species follows the Fibonacci sequence. Petals are one of the more well-known aspects of the Fibonacci sequence being represented in plants. What sets petals apart from other representations such as seed spiral and leaf arrangement, however, is that this simple method of differentiating among flowers that do and do not follow the Fibonacci order allows the paper to reach out to many people, even those who do not know how to find the Fibonacci sequence in other morphologies.

In addition, most of these plants were chosen based on how common they were throughout the U.S. and how easy it was to take care of them. (Table 1) Many of these flowers can endure difficult environmental conditions, such as cold and heat. For example, pansies are known for being resilient and able to survive frosts for a period of time. (4)

Results

Plants Following Fibonacci and Plants Following Non-Fibonacci	
Fibonacci Following	**Non-Fibonacci Following**
• Sweet Williams (Dianthus barbatus) • Pansies (Viola tricolor var. hortensis) • Hardy Cyclamen (Cyclamen purpurascens) • Wild Violet Petunias (Ruellia nudiflora) • Lyreleaf Greeneyes (Berlandiera lyrata) • Sweet Violets (Viola odorata)	• Alyssum (Lobularia maritima) • Kalanchoe (Kalanchoe blossfeldiana) • Matthiola (Matthiola incana) • Pink Evening Primroses (Oenothera speciosa) • Hardy Amaryllis (Hippeastrum x johnsonii) • Celandine Poppies or Wood Poppies (Stylophorum dipiphyllum)

Table 1. List of common names and binomial nomenclature of plants used. The left side is plants that follow the Fibonacci sequence while the right side is plants that do not follow the Fibonacci sequence.

Lifespan

Of the plants with petal numbers that follow the Fibonacci sequence, the Dianthus is a short-lived perennial, living for 10 years. (5) Pansies are biennials, living for only 2 years. (6) Meanwhile, Cyclamen, a perennial, can live up to 100 years! (7) Other flowers that have petal numbers following the Fibonacci sequence are Wild Violet Petunias (Ruellia nudiflora) and Lyreleaf Greeneyes (Berlandiera lyrata), which both live for 2-3 years. (8,9) Sweet Violets (Viola odorata), members of another type of flower that follows the Fibonacci sequence, are short-lived perennials, thus living for 3-5 years. (10,11) Based on the data, Pansies have a much longer lifespan than the other flowers in this group. All the flowers listed in this group (Fib) are able to live for at least 2 years, which suggests that these flowers are relatively resilient.

The flowering plants that do not follow the Fibonacci sequence (Non-Fib) have petal numbers that do not coincide with Fibonacci's numbers. Alyssum is an annual, living up to one year. (12) Being a perennial, Kalanchoe blossfeldiana can live up to 7 years. (13) Matthiola incana is a tender perennial, only living up to 2-3 years. (14) Other flowers that have petals that do not follow the Fibonacci sequence are Pink Evening Primroses (Oenothera speciosa) and Hardy Amaryllis (Hippeastrum x johnsonii), which take 2 years and 75 years respectively to complete their life cycles from beginning to end. (15,16) Another type of flower that does not follow the Fibonacci sequence are celandine poppies or wood poppies (Stylophorum dipihyllum), which are long-lived perennials, living for at least 10 years when in the right conditions. (17) Based on the data, Hardy Amaryllis have a longer lifespan than the other flowers in this group, but they live shorter lives compared to Pansies. Nevertheless, the flowers in this group (Non-Fib) are also able to live for at least 2 years, which suggests that these flowers are as resilient as those in Fib.

These lifespan differences between Fibonacci and non-Fibonacci following plants indicate that Fibonacci following plants live longer on average than non-Fibonacci following plants. However, as the error bars are overlapping, the difference in lifespan of plants of Fib and Non-Fib is not statistically significant. Each of the groups also have an outlier, representing pansies and hardy amaryllis in Fib and Non-Fib respectively (Figure 1).

Regardless, this data suggests the possibility that following the Fibonacci sequence in petal number leads to longer lifespans in flowering plants. We can form a connection between the flowers that follow the Fibonacci and crops that follow the Fibonacci sequence. Following that logic, the trends found in flowers that follow the Fibonacci can help find solutions to growing problems in food security and food supplies by helping us understand that plants that have longer lifespans on average live for longer. This may be possible because these plants may have less turnover when planted as crops.

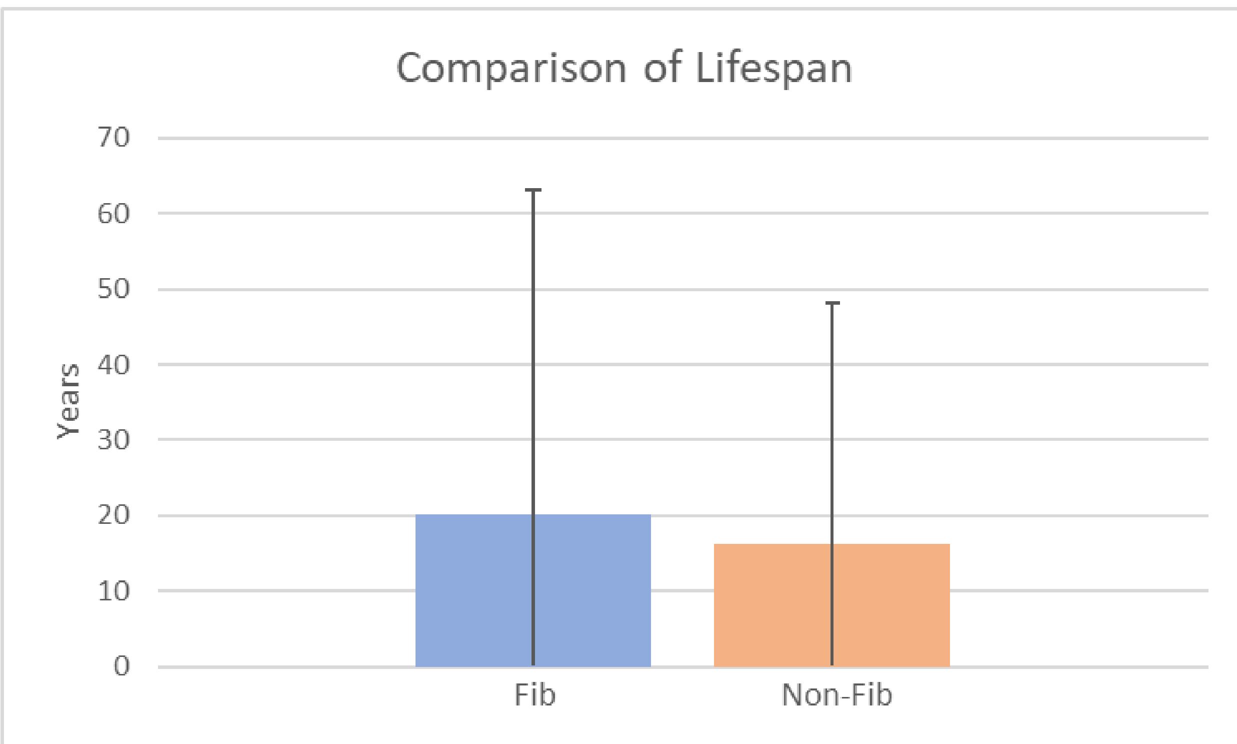

Figure 1. The average lifespans of Fib and Non-Fib plant species. Error bars account for the outliers, pansies and amaryllis, which have longer than average lifespans.

Pollinators

As a rule of thumb, bees and butterflies are the prominent pollinators of flowers. For this paper we will focus on these two pollinators and four additional common pollinators, hummingbirds, birds, moths, and bats. These pollinators contribute to cross-pollination, a process in which pollen is transferred by the pollinator from one plant to another of the same plant species for fertilization. (18) Each of these pollinators have unique attractors and methods of pollination. Hummingbirds are specifically crucial to flora in the United States. (19) Bees are attracted to flowers with bright white or blue petals, present nectar, and a landing platform to stay on. Butterflies are attracted by flowers that require full sun and give off a weak yet noticeable scent. Birds, like hummingbirds, are attracted to flowers with red, blue, orange, or white colors and sufficient nectar and pollen. Moths usually pollinate at night and are attracted to flowers with dull colors, strong odor, and sufficient nectar and pollen. (20)

Fib attracts a variety of pollinators. Sweet williams are pollinated by butterflies, and hummingbirds (Figure 2). (21,22) However, the flower does not attract bees due to its dark red color shading. (23) Hardy cyclamen are pollinated by bees (Figure 2). (24) Violet petunias attract bees, hummingbirds, and butterflies (Figure 2). However, bees do not benefit from petunias as much because petunias provide insufficient nectar or pollen. (25) Lyreleaf Greeneyes are pollinated by bees, butterflies, and hummingbirds. They are also nocturnally pollinated by bats (Figure 2). (26) Violas and pansies alike are pollinated in the early spring by bees, butterflies, moths, and other insects coming from hibernation (Figure 2). (27–29) However, pansies are one of the easiest plants to pollinate due to its bright colors and ability to produce a lot of nectar to support the pollinators returning from hibernation in the early spring. (30)

Of the first flowers listed in Non-Fib, Kalanchoes are pollinated by bees, ants, butterflies, and birds (Figure 2). (31,32) Matthiolas are pollinated by bees (Figure 2). (14) Alyssums attract bees, flies, and butterflies (Figure 2). (33) Hardy amaryllis attract carpenter bees and moths; while some are able to self-pollinate, these flowers can rely on cross-pollination as well (Figure 2). (34) Pink evening primroses, known for their sweet scents and light, yellow colors, are appealing to bees and butterflies (Figure 2). Along with lyreleaf greeneyes, they are also nocturnally pollinated by moths. (35,36) Celandine poppies are pollinated primarily by bees (Figure 2); their seeds are contained in their fruits with fuzzy appearances. (37,38)

Almost all the flowers listed above are pollinated by bees. However, plants in Fib and plants in Non-Fib have differences in their reliances on cross-pollinations, as shown by Figure 2. More flowers in Group A depend on a variety of pollinators for cross-pollination than flowers in Group B. This is a significant finding because relying on multiple pollinators rather than a single pollinator, such as the bee, allows plants to fare better in events where changes can occur and cause some populations of pollinators to dwindle.

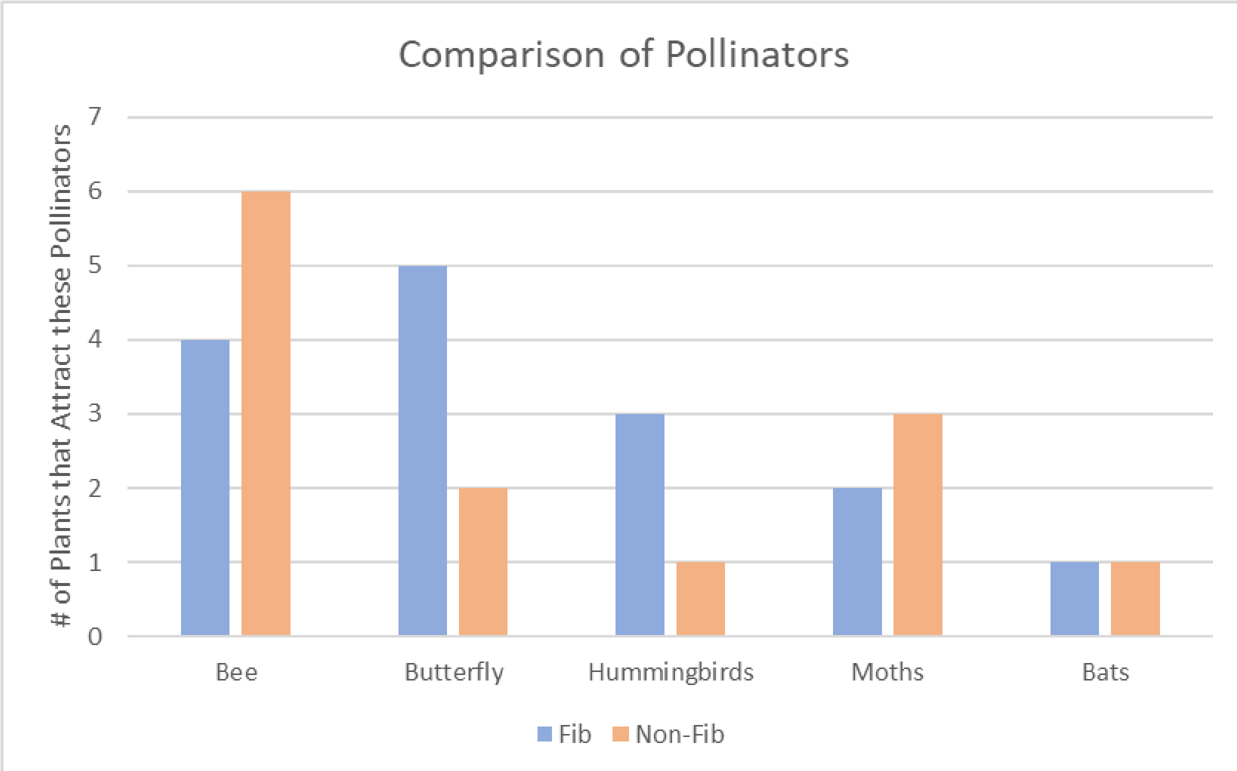

Figure 2. Number of flowers that are pollinated by each pollinator in Fib and Non-Fib.

In Fib, sweet williams, hardy cyclamen, lyreleaf greeneyes, and violas can rely on self-pollination, a process in which the pollen from the anther is placed onto a stigma that makes use of the pollen in the flower part of the same plant; violet petunias and pansies mostly rely on cross-pollination. (12,39–43) In Non-Fib kalanchoes, alyssums, hardy amaryllis, pink evening primroses, and wood poppies are able to self-pollinate; matthiolas cannot self-pollinate and needs to rely on cross-pollination. (44–49)

The important distinction between cross-pollination and self-pollination is the dependence on pollinators, which include but are not limited to bees, butterflies, and hummingbirds. Plants in Fib are found to attract more pollinators than plants in Non-Fib, which demonstrates Fib's ability to depend on cross-pollination, a more reliable method of transferring genes from parent to offspring than self-pollination. On the other hand, more plants in Non-Fib are able to self-pollinate than those in Fib. This evidence may indicate that plants in Fib are successful enough with cross-pollination and thus do not need to rely on self-pollination for chances of survival and reproduction as much as plants in Non-Fib.

Cross-pollination serves a better purpose of ensuring plants' survival than self-pollination. Cross-pollination allows parents to pass down a variety of traits to the new generation of plants. On the other hand, self-pollination is a process that only limits the traits to one progenitor and therefore produces little to no variety in the new generation. More genetic variety is better for survival because environmental conditions are constantly changing; not one trait fits all conditions throughout history. Having more traits within a population produces greater chances of survival in the environment, even when faced with drastic changes. Therefore, when compared to self-pollination, cross-pollination serves as the better option for the survival of plants. This is crucial to note because gradually warmer global and regional weather conditions can set off many changes to crop yields and food supplies.

Climate change will cause not only a greater likelihood of extreme weather events occurring, such as floods and droughts, but also a greater severity to such occurrences. Floods and droughts are leading causes of the decline in annual food supplies in semiarid and arid areas, which take up approximately 30% of the world's land and are home to around 40% of the human population as of 2021. (50,51) South Asia and Europe are the leading agricultural producers in the world. As of 2023, India, one of the South Asian countries, is a close second after the United States in the amount of arable land, and 69% of India is made of arid, semiarid, and dry sub-mid regions. (52,53) As a result, plants that do endure the increased number of floods and droughts that devastate regions would contribute heavily to food supplies worldwide. Exploring the evolutionary advantage of plants that follow the Fibonacci sequence can be crucial to supporting global food supply throughout climate change.

Tolerance to Weather

Living around the world, plants face a diverse assortment of weather conditions. That variety comes with a preference for some environments over others. For example, some plants need more sunlight to survive while others do not and instead prefer the shade. The tolerance to environments that may or may not be preferable for the development of the plants indicates possible evolutionary advantages between Fib and Non-Fib; in this study tolerance is measured by the number of USDA hardiness zones that these flowers are placed in. Hardiness zones are standards that are used to indicate whether plants can survive all year long at specific locations; these consider the highest and lowest temperatures and the amount of precipitation in an area. (54) Furthermore, resistance to sudden environmental changes is important to the survival of plants. Droughts are periods during which little to no rain occurs in the area. As plants rely on water for the cellular process of photosynthesis to make their own food, resistance to droughts can determine life or death for plants, which will be examined later in this section.

Of all the plants that follow the Fibonacci sequence, lyreleaf greeneyes have the most resistance to a variety of temperatures; they are cold tolerant and very heat tolerant. (26,55) Lyreleaf greeneyes require full sun to partial sun and reside in hardiness zones 4 to 10. (56) They normally prefer full sun, but are able to tolerate light shade for small periods of time.41 Sweet williams are drought tolerant. (57) Although different species of sweet williams are able to handle living in diverse climates, varying from hot climates in North Africa to cold climates in arctic regions of North America, the specific species used throughout this research study is Dianthus barbatus. D. barbatus resides in USDA hardiness zones 3 to 9. They are heat tolerant until above 85º F: above this temperature D. barbatus will become dormant. They are cold tolerant but can only handle light frost and cannot survive high humidity. (58) Hardy cyclamen prefer full sun, at least 14 hours of sunlight specifically, and cannot tolerate large amounts of shade. (59) They are very cold tolerant and can handle freezing winters; however, hardy cyclamen are not heat tolerant. (60,61) Hardy cyclamen are also moderately drought tolerant, but like sweet williams, the survival of cyclamen depends on the conditions of humidity. (62,63) Hardy cyclamen reside in hardiness zones 4 to 8. (64) Violet wild petunias prefer partial shade to full sun, which is a relatively large range of the amount of sunlight a plant can tolerate. (65,66) Violet wild petunias are heat tolerant and cold tolerant; they are also drought tolerant if living in high humidity. (67) Violet wild petunias reside in hardiness zones 8 to 11. Sweet violets and pansies require similar environmental conditions: they both need moderate amounts of sunlight and are tolerant to shade; they lack tolerance to droughts because they reside in humid areas, such as forests; and they are cold tolerant and moderately heat tolerant. (68,69) However, the similarities end when comparing hardiness zones of sweet violets and those of pansies. Sweet violets have hardiness zones 4 to 9 while pansies have hardiness zones 2 to 10. (70)

On the other hand, out of the plants in Non-Fib, sweet alyssums have the resistance to all the listed weather conditions. Sweet alyssums are drought tolerant, heat tolerant, and frost resistant. (71) Although they require at least 6 hours of sun once a day, they can live with full sun to partial shade. Sweet alyssums reside in hardiness zones 5 to 9. (72) Kalanchoe blossfeldiana live on full sun to partial shade, but they can tolerate light shade for short periods of time. (73,74) They reside on hardiness zones 10 to 12, so they are heat tolerant but not cold tolerant. (75,76) Kalanchoe blossfeldiana are also resistant to drought. (77) Matthiola incana prefer partial shade and cannot tolerate too much sunlight. (78) They reside in hardiness zones 7 to 10, and they are neither heat, cold, or drought tolerant.14 Therefore, Matthiola incana are the most fragile species of flower in both groups of flowers documented in this research paper. Pink evening primroses need full sun. (79) They inhabit hardiness zones 4 to 9 and they are heat tolerant and drought tolerant. (80,81) They are also cold tolerant as they attract many pollinators that come during the coldest time of the day: late evening to early morning. (82) Hardy amaryllis can live in full sun to partial shade, but they need at least 6 hours of direct sunlight to thrive. (83) They reside in hardiness zones 5 to 9; they are heat tolerant, cold tolerant, and extremely drought tolerant. (84–86) Celandine poppies prefer partial sun to full shade, and they cannot tolerate long periods of direct sunlight. (87,88) They reside in hardiness zones 4 to 9, and they are heat, cold, and drought tolerant. (89)

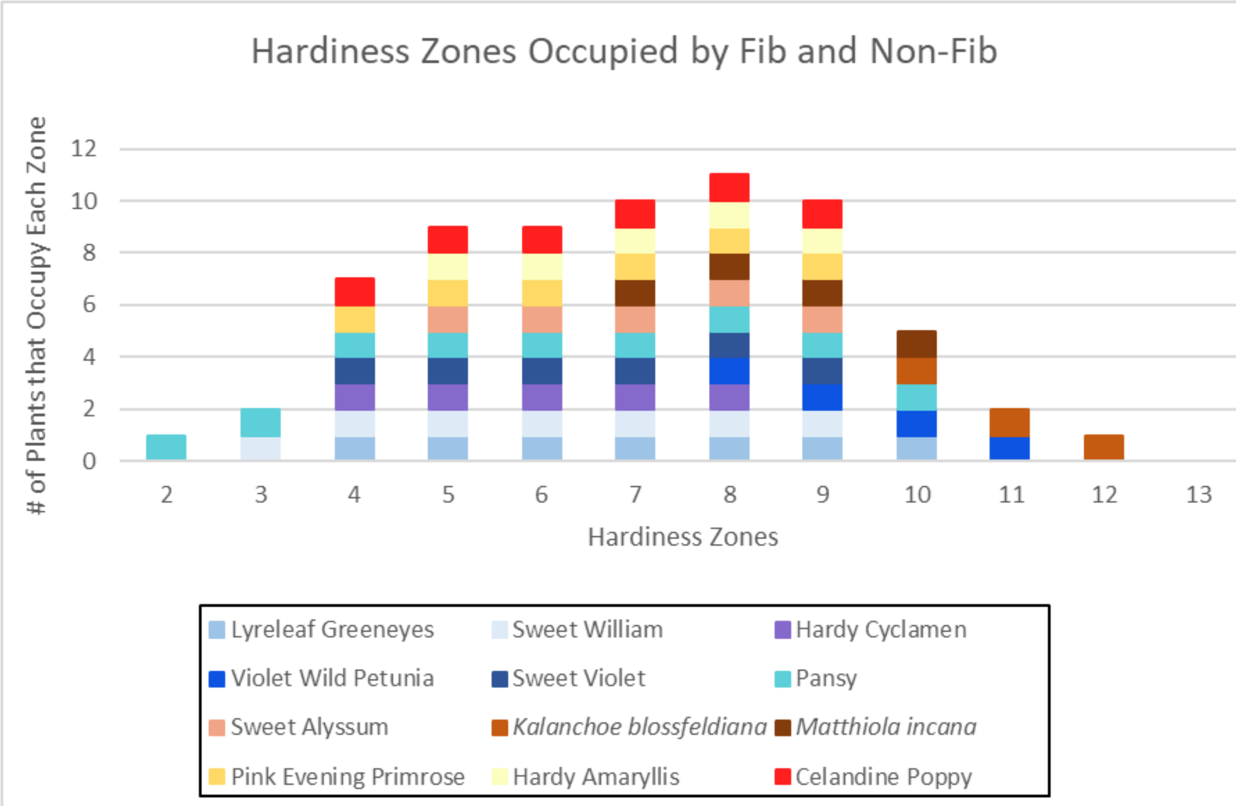

Figure 3. Number of flowers in Fib and Non-Fib that reside in each USDA hardiness zone.

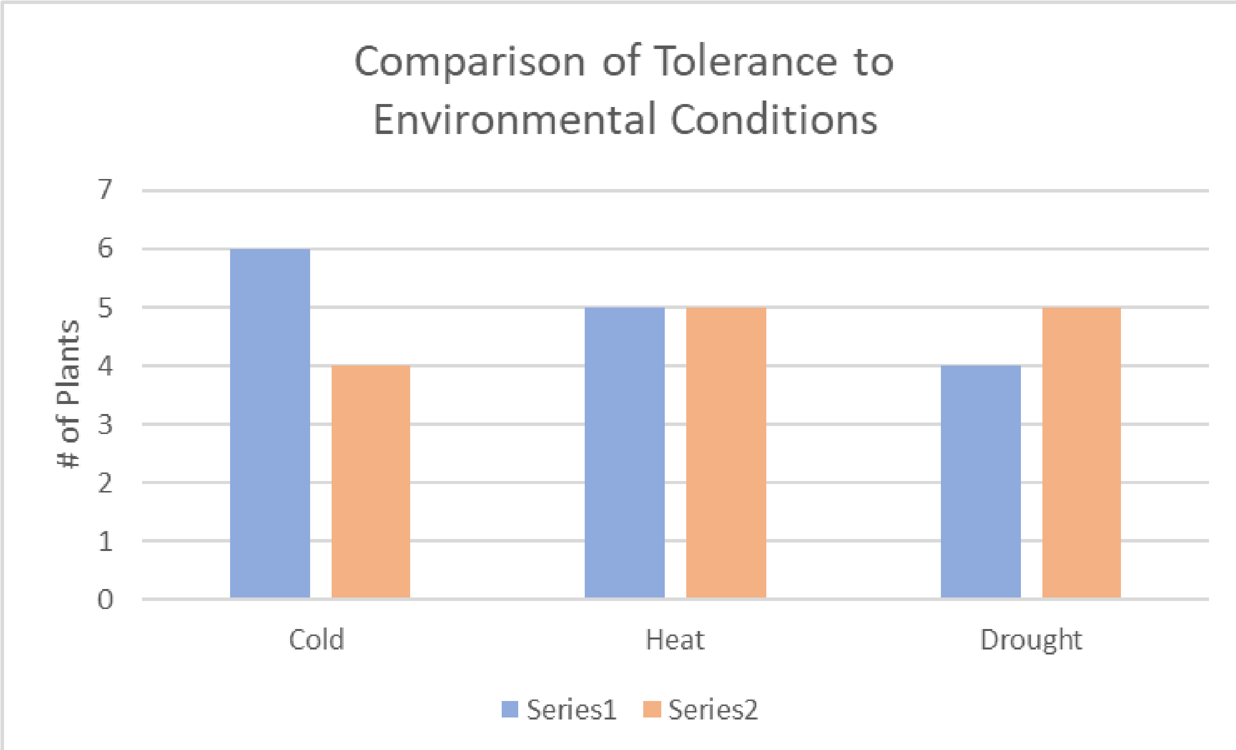

Figure 4. Number of flowers in Fib and Non-Fib that tolerate cold, heat, and droughts.

The major outliers in this section covering weather tolerance are pansies and Matthiola incanas. Pansies reside in zones 2 to 10, the majority of all the zones marked in the US. In contrast, Matthiola incana are declared half-hardy due to their ability to tolerate frost once, but they are only able to survive all-year in zones 7 to 10, a relatively small range of zones compared to other species in this study. Additionally, Matthiola incana are claimed to lack tolerance to the cold, heat, and drought. The pansies and Matthiola incana may have skewed the results in Fib's favor (Figures 3 and 4). (14)

According to this study, plants in Fib reside in a wider range of hardiness zones with greater consistency than those in Non-Fib. Similarly, more plants in Fib tolerate the cold than flowers in Non-Fib. On the other hand, an equal number of plants in Fib and Non-Fib are tolerant of the heat and more plants in Non-Fib are tolerant of droughts than plants in Fib. This is important to note because as climate change causes frequent, drastic temperature changes and weather events, the plants that can survive all-year in a wide range of areas would be preferred over those that are limited to certain areas for germination and proliferation.

Discussion

Fibonacci following plants (Fib) have shown to have greater life spans on average than non-Fibonacci following flowers (Non-Fib). However, the difference in lifespan of plants covered in this study of Fib and Non-Fib are not statistically significant. In addition, Fib and Non-Fib each have an outlier in this section: pansies in Fib with the ability to live up to 100 years and hardy amaryllis in Non-Fib being able to live for 75.

Fib plants appear to live longer on average compared to Non-Fib plants; this indicates that Fib plants can live in current environmental conditions longer than Non-Fib plants can. However, the difference in average life spans of Fib and Non-Fib plants is not significant, so this alone does not support the evolutionary advantage of following the Fibonacci sequence. In future studies, I plan on expanding the number of plants' data collected to incorporate more types of plants that can belong in either Fib or Non-Fib. In Fib, violas and pansies are closely related flowers; therefore, using their data does not accurately reflect the data of the other types of flowers that follow the Fibonacci order, such as phlox and periwinkle flowers.

Most of the flowers in Fib and Non-Fib are propagated by bees, one of the most, if not the most, important pollinators of plants. Members of Fib and Non-Fib have similarities yet considerable differences in their data. Flowers in Fib rely on more pollinators than plants in Non-Fib and more flowers in Non-Fib are able to self-pollinate. These two results are important when taken together because these findings suggest that flowers in Fib attract enough pollinators to the point where they do not need to depend on self-pollination for survival and reproduction of their species. Cross-pollination, pollination by a third party, also allows for a greater variety of traits to be passed down from parent to offspring, making it a better option than self-pollination. Fib's stronger reliability to attract a greater variety of pollinators indicates that Fib succeeds in cross-pollination, which allows for the propagation of an array of traits beneficial to the organism, such as Notylia nemorosa's ability to produce fruit. (90) The fruit produced by Notylia nemorosa are able to protect the seeds in the plant and enable even more cross-pollination. (91) On the other hand, plants that undergo self-pollination produce offspring with traits that are limited to that of a single progenitor. This is not conducive to conditions that are constantly changing, such as the state of the world being rapidly affected by climate change.

Members of Fib consistently belong in a wider range of USDA hardiness zones than those of Non-Fib. USDA hardiness zones are used as a measurement of which zones where these plants are most comfortable in living all year. Therefore, this finding indicates that flowers of Fib are able to survive in a wider range of temperatures than flowers of Non-Fib, which can determine chances of survival in an environment in which climate change causes drastic and frequent temperature changes, mostly increases in temperature. (92)

On the other hand, 3 different findings were found regarding tolerance to relatively short-term changes in weather conditions. From the data collected, more plants in Fib are tolerant of temporarily colder temperatures than those in Non-Fib, plants in Fib and Non-Fib had the same number of plants heat-tolerant, and more plants in Non-Fib were shown to be drought-tolerant than those in Fib. Based on this evidence, it can be concluded that more Fib plants are tolerant to the cold while those in Non-Fib are tolerant to droughts. However, the difference in data does not appear to be significant based on the notion that only the data of 12 species of plants were collected in this study and many species from Fib live in humid environments. Regardless, plants in the Non-Fib category would be able to survive droughts more often, which indicates that they would have greater chances of survival during climate change.

More research needs to be conducted considering that data from only 12 plant species was collected, which does not completely reflect the trends found in this study involving flowers that do or do not follow the Fibonacci sequence. However, based on the evidence collected, plants in Fib have a slightly stronger evolutionary advantage than those in Non-Fib in terms of life span and pollination, which may allow these plants to gain the upper hand in surviving in an environment that will be constantly changing. As evolution occurs slowly in plants, looking into which kinds of plants have better chances of survival in a variety of conditions allows for us to act quickly to promote the growth of those plant species. However, in order to form a stronger conclusion from this study, data of more plant species ought to be implemented along with recording data on a wider arrangement of qualities that are conducive to a plant's survival, such as tolerance to pesticides and responses to external and internal stimuli like wounding from pests.

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