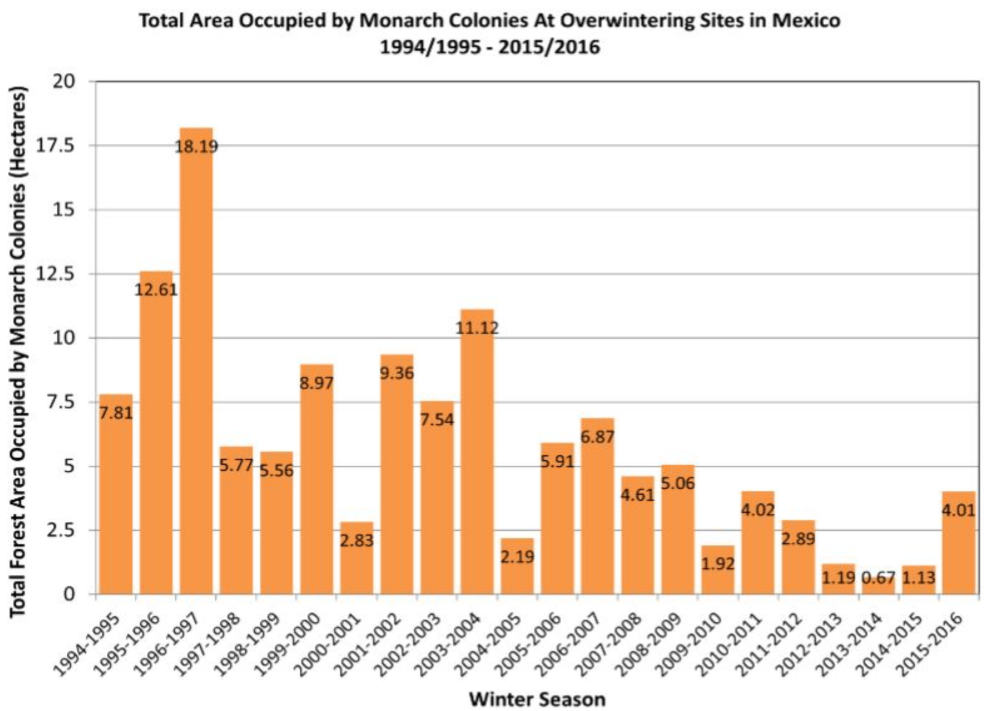
Picking Plants for the “Monarch Highway”
Part 1: Background

Monarch butterflies are well known among North Americans for their bright orange color and their 2,500 mile migration from Mexico to Canada each year. The monarch butterfly has great cultural importance, especially for Mexicans and Mexican Americans, as they are often a symbol for returning spirits on the celebration of the Day of the Dead. Monarchs have a specific life cycle: they lay an egg on a leaf from a milkweed plant, and when the caterpillar hatches, it feeds exclusively on the milkweed plant until it is ready to pupate and become a butterfly. There are 3-4 generations of monarchs in the United States in the summer, but when fall comes, the adults who migrate to Mexico will overwinter there until they return to the US the following spring.

Monarch butterflies have recently received a lot of attention due to changes in their population size. Scientists record monarch populations based on the area they occupy in their overwintering sites in Mexico (Fig. 1).

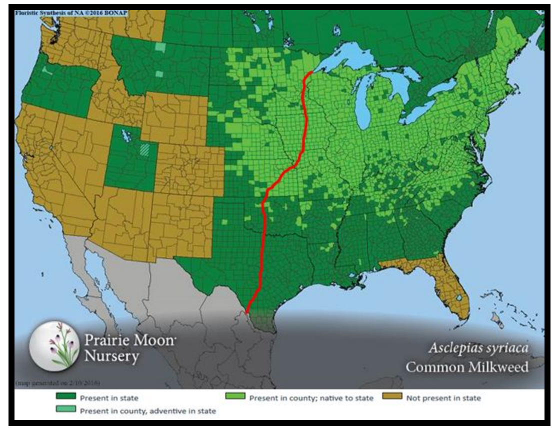


Courtesy of the Monarch Joint Venture. Data from 1994-2003 were collected by personnel of the Monarch Butterfly Biosphere Reserve (MBBR) of the National Commission of Protected Natural Areas (CONANP) in Mexico. Data collected from 2004-2016 were collected by the WWF-Telcel Alliance, in coordination with the Directorate of the MBBR.

1. What patterns do you notice in this graph?

2. What phenomena might explain the patterns that you see?

Although scientists don't all agree about the most important causes, one hypothesis is that a decrease in milkweed, a breeding ground for monarchs, may be causing the dramatic decrease in monarch numbers. There are many species of milkweed, but one important species for monarchs is common milkweed. This plant grows throughout most of eastern North America, and has historically grown along roadsides, in farmers' fields, and in other disturbed areas. However, due to the recent introduction of Roundup Ready pesticides, farmers fields are barren of milkweed because the pesticides kill them. This means that monarchs can travel a long ways before finding another milkweed plant that would be suitable to lay eggs on. With the growing threat of the monarch's extinction, individuals, scientists, environmental organizations, and governments are working to find a solution for the looming problem: how to save the butterflies.



Minnesota among other midwestern and southern states have come together to design a plan for the "Monarch Highway". The "Monarch Highway" will be along I-35, which runs 1,500 miles from Laredo, Texas to Duluth, Minnesota. Government agencies propose planting pollinator habitat, including milkweed, along the edges of the highway to provide nectar and breeding grounds for monarch butterflies.

As these kinds of restoration practices are occuring, more and more people are wondering how to best support the growth of milkweed, a plant which humans have historically viewed as a weed.

Part 2: Research Overview

Emily is an environmental researcher at a college in Minnesota. She is working with researchers and educators in many states to try to find out whether or not common milkweed is locally adapted to its environment. Locally adapted species are the opposite of an invasive species. When an invasive species enters an environment with no natural predators, they often take over the area and can cause great harm to the other species that already live there. In contrast, a species that is **locally adapted** to one area will perform less well if it is displaced from its natural environment. Each population of a locally adapted species has evolved specific environmental needs, and researchers can test for local adaptation by measuring the change in a plant's fitness, or its overall performance, when individuals are removed from their original environment and grown in a different environment.

If common milkweed is locally adapted to its own particular region, then it could be challenging to collect enough of the right seeds to grow along the highway. For example, the common milkweed that grows in northern Minnesota, may be locally adapted there and may not do as well in Iowa, or vice versa. Even worse, if lots of non-local seeds are planted in an area with a small local population, the extra plants may decrease the overall fitness of the whole population. We don't know much about the patterns of local adaptation in milkweed.

Emily and other researchers at colleges and schools across the country have agreed to do a seed swap to look for patterns of adaptation. Researchers trade seeds from different locations, plant all of them in a garden together, and measure them to see how well they grow. This is called a **common garden experiment**, and it's an important way to compare the differences in growth and other traits between populations, or **ecotypes,** that come from different areas.

3. Predict: If a milkweed plant was locally adapted to a region in Iowa and it was relocated to a common garden in Maine, how well would the Iowa milkweed do compared to the Maine milkweed?

Milkweed plants live for many years, so it can be difficult to measure their "**fitness**" at a single point in time. Every spring and fall, the researchers measure the number of stems, the height, stem diameter, plant mass, leaf number, **node number**. Nodes are places on the plant stem where leaves and other branches can grow (*Illustration by Jacqueline Nuzzo)*. They present as small bumps in pairs, one on either side of the plant. Nodes are a fantastic indicator of plant growth and fitness because the number of nodes that grow on a plant is often correlated with plant height, and nodes provide a cumulative mark of where leaves are or have been, even after the leaves fall off. These two correlated measurements combined give us the best indication of plant fitness, out of all of the other measurements. None of these measurements alone is a perfect indication of plant fitness, but they are probably all related.

Emily has taken node measurements of over 100 milkweed plants in her Minnesota common garden throughout the spring, summer, and fall of 2017 and 2018. She has been using seeds from 5 different locations and has named them Ecotypes A, B, C, D, and E. The source of each ecotype has been described in two ways: by its latitude and by the total distance away from the common garden at the college where Emily works. Below are data about the average node number measured for plants from each ecotype during the spring, summer and fall of each year. We use them to ask two related questions that will provide clues about local adaptation:

1. How does the distance between the place a seed comes from (ecotype origin) and the place it is grown (common garden site) affect plant growth traits?
2. How does the latitude of the place a seed comes from (ecotype origin) affect plant growth traits?

Part 3: Distance between University and Ecotype Origin

4. How does the distance between the ecotype origin and common garden site relate to local adaptation?

5. Predict: What relationship do you expect to find between distance and node number? Sketch a graph. Can you explain?

Table 1

2017								
Spring			Summer			Fall		
Eco.	Distance (km)	Avg. Node #	Eco.	Distance (km)	Avg. Node #	Eco.	Distance (km)	Avg. Node #
A	61	13.73333	**A**	61	21.25	**A**	61	11.57143
B	42	12.33333	**B**	42	18.6	**B**	42	0
C	844	11.15385	**C**	844	12	**C**	844	8.923077
D	0	11.52381	**D**	0	15.71429	**D**	0	6.928571
E	763	11.69231	**E**	763	17.42857	**E**	763	11.38462

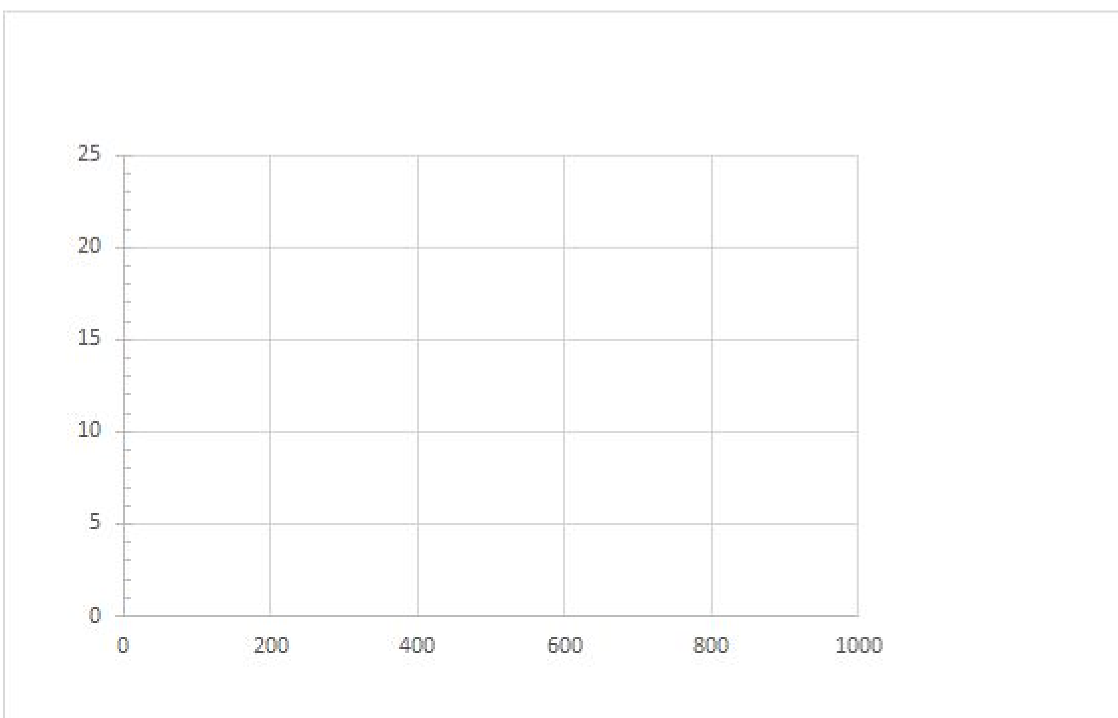
6. Which ecotype is local to Emily's University?

7. Why is it significant that Emily took the average of the number of nodes for all of the plants?

8. What does it mean for the average of a node to have a decimal point of .333?

9. In general, what happens to the number of nodes as time passes?

10. Plot the data for 2017 listed above on the graph below. Be sure to include a title, axis labels, a **trendline**, a legend, and different colors for spring, summer and fall.



11. What are we assuming when we use a trendline?

12. Please mark the boxes below based on the graph you designed.

How does your trendline look?			
	Increasing	Decreasing	Flat
Spring of 2017			
Summer of 2017			
Fall of 2017			

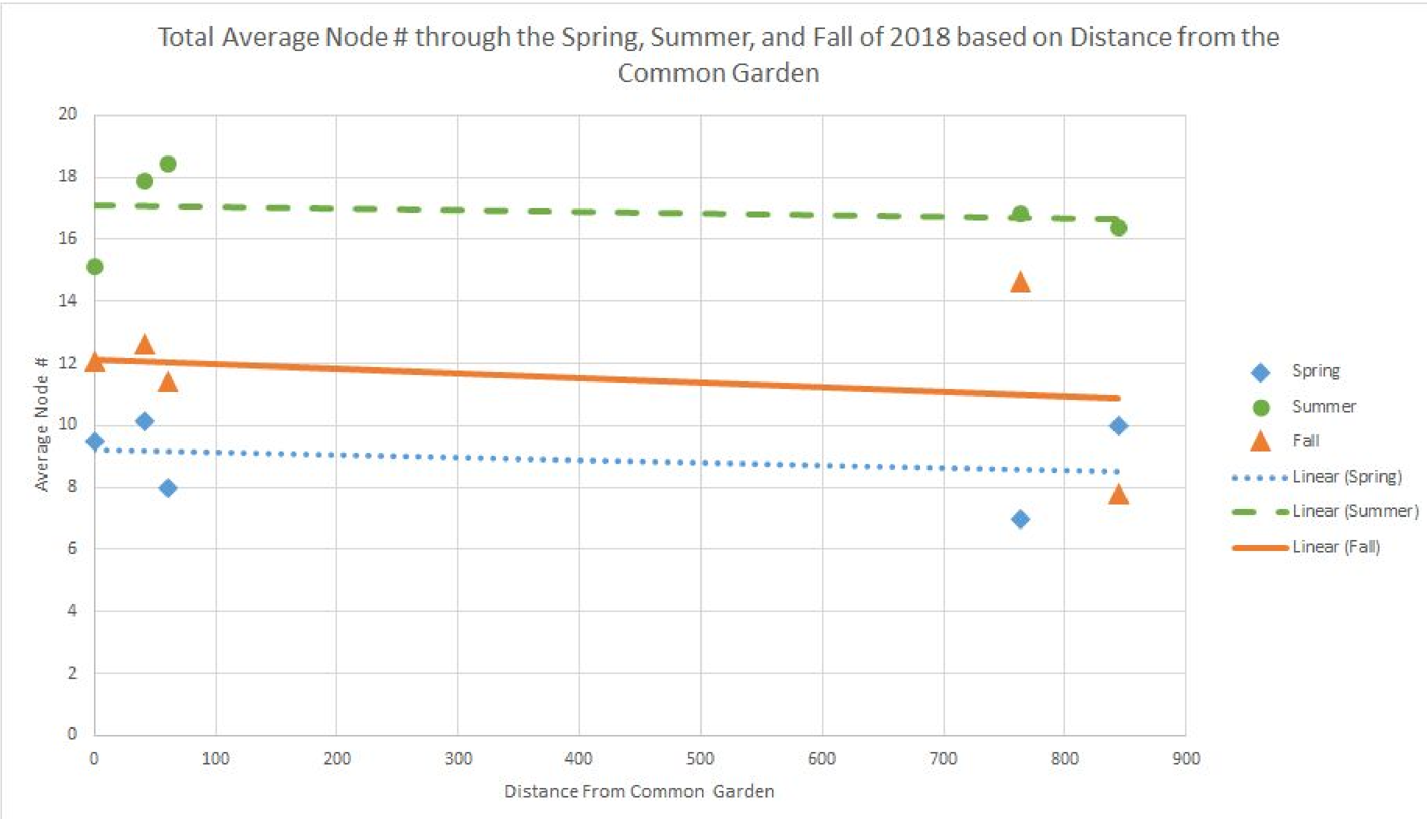
Which ecotypes do best in the common garden?			
	Ecotypes far away from the University	Ecotypes close to the University	About the same
Spring of 2017			
Summer of 2017			
Fall of 2017			

Do these data support local adaptation?			
	Yes	No	Not sure
Spring of 2017			
Summer of 2017			
Fall of 2017			

13. Based on this information, do you think our results support local adaptation of milkweed from Minnesota? Make a claim, refer to evidence, and support your answer with reasoning.

Part 4: Distance Graph Reading

The graph below is the data for the average node number in the spring, summer, and fall of 2018, similar to the graphing activity you did above. Examine this graph and answer the questions below.



14. Please mark the boxes below based on the graph above.

How does the trendline look?			
	Increasing	Decreasing	Flat
Spring of 2018			
Summer of 2018			
Fall of 2018			

Which ecotypes do best in the common garden?			
	Ecotypes far away from the University	Ecotypes close to the University	About the same
Spring of 2018			
Summer of 2018			
Fall of 2018			

Do these data support local adaptation?			
	Yes	No	Not sure
Spring of 2018			
Summer of 2018			
Fall of 2018			

15. Comparing the graphs between the 2017 and 2018 data, do you think our results support local adaptation of milkweed from Minnesota?

16. What other information has Emily collected that we can use to explain this phenomenon?

Part 5: Latitude

Latitude can tell us more about the **climate** where each ecotype originates, which is important because climate is predicted to strongly impact the way a plant grows, and plants might well be adapted to their local climate. For example, plants that evolved in a place where they receive lots of sun exposure, like plants in southern states, may struggle to grow in an area that receives less sun exposure, like northern states.

Minnesota and Wisconsin have a highly variable climate of extremely hot summers and very cold winters, with rainfall throughout the summer months and receives significant snow in the winter. Both Minnesota and Wisconsin have a growing season of about 160 days.

New York, like Minnesota and Wisconsin, has hot summers and cold winters, but sees some rain all year long. New York can get a lot of snow, and only has a growing season of 135 days.

Virginia on the other hand, experiences hot and humid summers and mild winters. Virginia gets rainfall year-round, and receives minimal amounts of snow in the winter months. Virginia sees the longest growing season, compared to the other three states, of 182 days (NOAA).

17. Predict: How do you think the length of the growing season affects how milkweed grows?

18. Predict:Do you believe that milkweed that from another location will look different because of the differences in growing season?

Plants and animals look and behave differently over time, because they go through life stages. Life stages can include blooming, loss of leaves, hibernation, etc. **Phenology** is the timing of these life events, like plants bloom in the spring,plants lose their leaves in the fall, and bears and other mammals hibernate in the winter. Phenology could tell us a lot about how milkweed reacts to its environment. However, we have not measured phenology yet, because can be complicated to measure. It takes many years to retrieve consistent and accurate measurements of a species.

19. Predict: How could phenology indicate that a milkweed plant is doing well in its new environment?

The table below is the data for the average node number in the spring, summer, and fall of 2017, similar to the table you saw in Part I. Examine this table and answer the questions below.

Table 2.

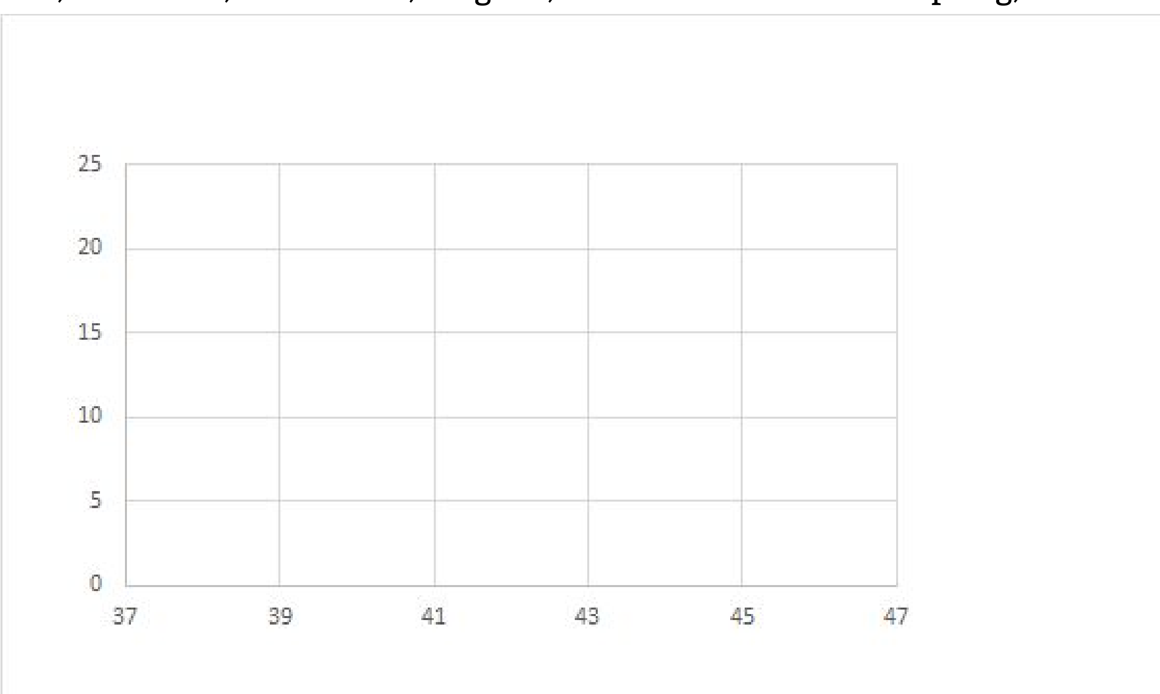
2017					
Ecotype	Latitude	Longitude	Spring Node #	Summer Node #	Fall Node #
A	44.9012	91.8926	13.733	21.25	11.571
B	44.005	92.4605	12.333	18.6	0
C	44.78067	73.3778	11.154	12	8.923
D	44.4658	93.1908	11.524	15.714	6.929
E	37.39987	79.1465	11.692	17.429	11.385

18. Previously, we looked at the distance from Emily's university to the other places where the seeds originated. Please draw lines from Emily's university to the other ecotypes, and label the four other ecotypes using the distance measurements from Table 1. Then use Table 2 to draw the latitude and longitude lines over the ecotypes using the provided latitude and longitude.

19. What is the relationship between latitude and distance? How are they different?

20. Using these diagrams, tables, and explanation above, summarize the relationship between latitude and climate?

21. Plot the latitude data for 2017 listed above on Table 2 the graph below. Be sure to include a title, axis labels, a **trendline**, a legend, and different colors for spring, summer and fall.



22. Please mark the boxes below based on the graph you designed.

Which ecotypes do best in the common garden?			
	Ecotypes at a different latitude to the University	Ecotypes at a similar latitude to the University	About the same
Spring of 2017			
Summer of 2017			
Fall of 2017			

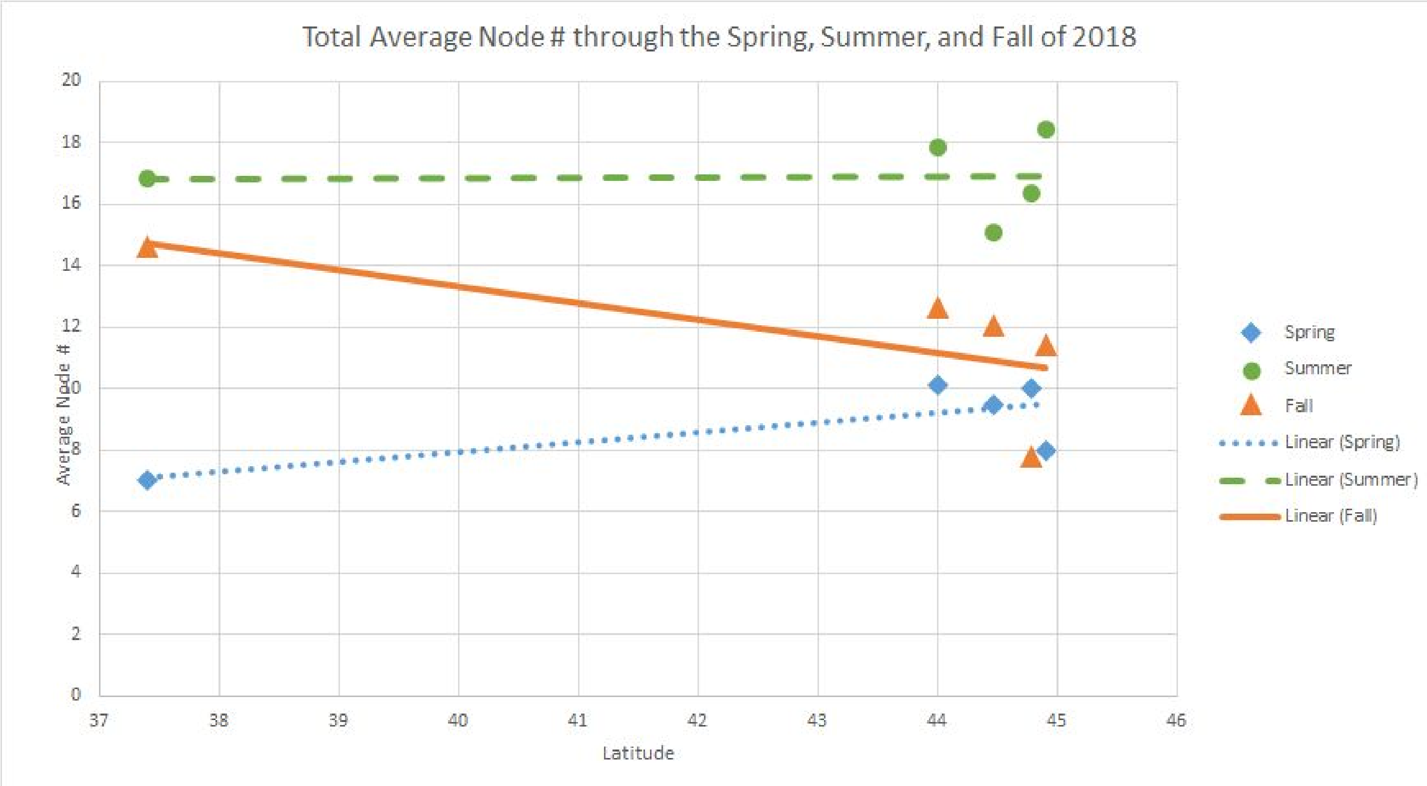
Does this data support local adaptation?			
	Yes	No	Not sure
Spring of 2017			
Summer of 2017			
Fall of 2017			

23. What changes to the experiment would help you to become more confident in the trendlines you have been drawing?

24. Based on this graph alone, do you think our results support local adaptation of milkweed from Minnesota?

Part 6: Latitude Graph Reading

The graph below is the data for the average node number in the spring, summer, and fall of 2018, similar to the graphing activity you did above. Examine this graph and answer the questions below.



25. Please mark on the x-axis which end would have the longer and the shorter growing season.

26. Please mark the boxes below based on the graph you designed.

Which ecotypes do best in the common garden?			
	Ecotypes at a different latitude than the University	Ecotypes at a similar latitude to the University	About the same
Spring of 2018			
Summer of 2018			
Fall of 2018			

Does this data support local adaptation?			
	Yes	No	Not sure
Spring of 2017			
Summer of 2017			
Fall of 2017			

27. Based on this graph alone, do you think our results support local adaptation of milkweed from Minnesota?

28. Comparing the graphs between the 2017 and 2018 data, do you think our results support local adaptation of milkweed from Minnesota?

29. Go back and review the definition of phenology. How do you think climate affects the phenology of milkweed plants?

Part 7: Conclusion

30. Drawing on what you have learned from the last four graphs, do you believe that milkweed is locally adapted to Minnesota? Why or why not? Please use claim, evidence, and reasoning.

31. What other information do we need to know in order to understand local adaptation in milkweed better?

32. Would you recommend legislators to build the “monarch highway” along I-35 based on what you’ve learned? Why or why not? What cautions do you recommend to them?