Teaching an Old Plant New Tricks

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What always goes up but never comes down? Age. This pun, as simple as it may sound, is a universal truth. There are very few creatures that can escape from the hands of father time. When someone thinks of ageing, a plant usually does not really come to mind. One does not often see news reports on "The Oldest Plant Celebrates Another Birthday." But much like humans, plants also age, so it is important to understand just what that means for our green friends.

One might ask, why is it important to study plants; they are so simple. It is easy to forget how paramount plants are for human survival as well as how complex they can be. Ever since the agricultural revolution some 12000 years ago, humans have cultivated and lived off various plant species. Agriculture is still the single largest use of land to this day, with half of the world's habitable land being used for agriculture. As such, it is even more important to understand the nature of these organisms and their ageing processes. Determining their life cycles and ageing processes will help farmers, which helps the human race as a whole. For example, the quest for the golden rice grain that can be grown in even the harshest of conditions to fight world hunger is still occurring. Understanding how age affects growth and plant physiology will further this quest, getting us a step closer to ending world hunger.

However, world hunger is only half the battle. The climate and environmental conditions are declining, and this change may pose a huge threat to human survival. Figuring out how environmental stressors and seasonal changes interact with the age of the plant will further our understanding to fight climate change. The plants of the world, especially forests, recycle tons of carbon dioxide from the air daily. So, understanding the basic ageing biology of plants will help us in the war against climate change. As we learn more about plants, the better we get at utilizing them in a more effective manner.

While this only scratches the surface of the importance of plants, I hope to have given a convincing argument for the importance of studying plants and their biological ageing processes. To understand how ageing affects plants, a graduate student and professor performed an experiment that took almost a full decade. A recent study by Brandie M. Quarles and Deborah A. Roach, from the University of Virginia, aimed to understand what ageing for a plant means in multiple contexts. Quarles and Roach asked three main questions for this study, which can be summarized into one overarching question: how multiple traits differ in old plants and young plants placed in multiple environments.

The plant of choice for Quarles and Roach was ***Plantago lanceolata*** (shown on the right), known as ribwort plantain, narrow leaf plantain, or ribgrass (Stewart 1996). This plant is commonly seen in grass fields and sides of roads. In natural grasslands it can grow under pretty low fertility conditions, meaning it does not require super nutrient rich soil or the best soil composition to survive (Stewart 1996). These plants' growth period occurs twice in a year, in March and September. This species also has the ability to reproduce during their first year of life.

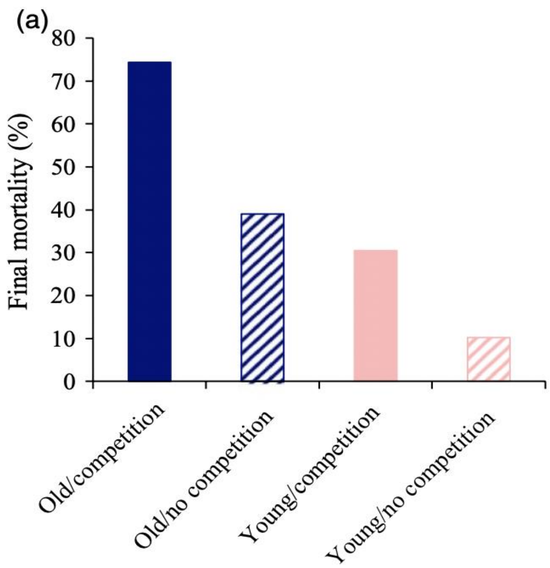
One property which is heavily emphasized is competition among plants. The world of competition among plants might seem like an obscure topic, however unbeknownst to the human eye, plants wage war underground. This specific plant is capable of using nutrients from deeper soil layers, because of its ability to develop greater proportions of its roots deeper than other plants (Stewart 1996). This means, when fertility is a problem for other more sensitive plants, the ribgrass can survive and outcompete them. Belowground competitive ability is correlated with the properties of the roots of the plant including how dense, how big, how flexible, and how enzyme rich they are (Casper & Jackson 1997). The above ground battle is a simple game of who's the bigger plant with bigger leaves/surface area to absorb the most sun (Casper & Jackson 1997).

Another important property to note is the plant's efficiency. We learn in elementary school that during photosynthesis plants use energy from sunlight plus some magic (aka a bunch of chemical reactions), to turn carbon dioxide and water into oxygen and sugar (glucose). To measure how successfully and efficiently any particular plant is doing this feat, scientists use a number called Optimal Quantum Yield (Ritchie 2006). This number can range from high, for "normal" healthy plants, to low values (Ritchie 2006). A stressed plant would have a lower value, with a value below 0.6 possibly indicating there is severe damage to the plant (Ritchie 2006).

The researchers also looked at how ageing affects a plant's reproductive capabilities. They did this by looking at the plant's inflorescences (shown on the left), which is a really fancy word for the complete flower head of a plant including stems, stalks, bracts, and flowers. These structures are important for plant reproduction and are very sensitive to natural selection (Kirchoff & Claßen-Bockhoff 2013). The number of seeds produced per inflorescence, the weight of the seeds produced, and the number of mature inflorescences produced per plant are all important in determining the reproductive success of the plant (Kirchoff & Claßen-Bockhoff 2013).

Quarles and Roach took over seven years to complete, which is understandable as studying ageing by definition is a timely process. Seeds of the ribwort plant were collected and planted in a greenhouse in two batches, either 1 year or 6 years prior to the start of the study. So, the old plants were 6 years old and the young plants were 1 year old at the start of the study. At the start of the study, the old and young plants were transplanted from the greenhouse into a field, in randomly assigned groups. There were 4 treatment groups in the experiment: old plants with competition, old plants without competition, young plants with competition, and young plants without competition. Plants in the competition group had other shrubbery and other neighboring plants near them, while the no competition group had no other greenery surrounding the plant.

Over the one-year observational period, the study measured and compared growth, physiology (efficiency), and reproduction of the plants. This was done by counting the number of leaves on all the plants and dimensions of the leaves every 4-5 weeks. The results for the growth analysis are shown on graph (a). It tells us that older plants, in general, had a higher overall mortality compared to younger plants. Both groups had the highest mortality at the start of the growth period. However, competition was also a very important factor in determining mortality rates. The plants in the competition group had a higher mortality rate than the non-competition group, within the same age group. From the results, we can see that age group is a better determinant of mortality than competition. They also found that the size of young and old plants is very similar in the presence of competition; but without competition the young plants were greater in size.



Knowing these factors of mortality and size, a company or scientist trying to combat climate change is much better equipped. The longevity of plants is an important factor to help reduce climate change because it is much more cost effective to have longer living and larger plants. Climate change combatants can use this information and choose younger seedlings overall and plant them with enough space to reduce competition. With these factors, the plants will live longer and grow larger, thus drawing more CO_2 out of the air and help fight global warming. These same factors can be used by farmers and agriculturists when determining how to plant their crop for the next cycle, to maximize crop yield and curb crop death. They could even prepare better for the higher rates of mortality during the start of the growth period, for example by providing extra nutrients or planning the planting time. Larger crops + more durable crops = more food.

The study also measured the efficiency of the plants. This was measured using special equipment that recorded the Optimal Quantum Yield and chlorophyll content in the plants. The results showed us that younger plants had a higher Optimal Quantum Yield, meaning they were more efficient at photosynthesis than older plants. However, within the old and young plants, there was no difference in efficiency between the competition and no competition groups. They also found that the efficiency changed throughout the year when comparing the age groups and older plants had lower efficiency than their younger counterparts during the winter months. The chlorophyll content mimicked this trend. Overall, younger plants were more efficient in turning carbon dioxide into sugar and oxygen, and better able to adapt to the changes in the environment throughout the year.

Plant efficiency is very important for farmers and agriculturists, since their livelihood and humanity's survival depend on how efficiently they can grow the food. Much like mortality, these findings reinforce the importance of selecting younger seedlings, with more efficient plants, that perform photosynthesis better, the plants are able to better adapt to their surroundings and provide more fruits and vegetables. Even futuristic vertical greenhouses benefit from these findings. They can replace the older organisms, and recycle the spots with younger versions, which are more efficient and live longer. In terms of climate change, a more efficient plant means more CO_2 being pulled out of the atmosphere per plant. With limited resources and time, every molecule counts.

The final trait measured by Quarles and Roach was reproduction. Reproduction was measured by counting the number of mature inflorescences per plant, how many seeds produced per inflorescence, the weight of the seeds, and how many of those seeds were germinated. Surprisingly, the competition was a much better determinant of reproductive success. The plants in the competition treatment group, regardless of age, produced far less mature inflorescences and seeds per plant than the no competition treatment group. However, when looking at the weight of the seeds, older plants produced lighter seeds than young plants. Overall, it seems that in terms of reproduction, the presence of competition seems to be the biggest factor affecting this trait.

Reproductive success is key for plant breeders and conservationists who depend on this very trait. These results help them understand that instead of focusing on the age of the plant, they should center their attention on competition. As a result, they would really focus on keeping the shrubbery and other plants a minimum, while giving plenty of space between specimens.

Overall, Quarles and Roach's findings sheds light on the importance of many characteristics when it comes to growing plants. From the average plant enthusiast, who grows plants in their house for fun, to farmers, who grow to feed this world, to climate change scientists, who are valiantly trying to slow down global warming, these findings are incredibly important. They tell us how important it is to select young plants, plant them with enough space, and keep other greenery to a minimum around them. These factors help create the longest living, largest, more efficient, and reproductively successful plant. Armed with this knowledge, scientists can further their research on the golden grain and plans for reforestations. This research will not only help plant related careers, but humans in general. After all, if each farmer can grow one extra fruit or each conservationist can keep one extra plant alive longer, it is not just them who benefit, but all of humankind. Quarles and Roach's study is just the start, there is still much to be discovered. The effects of ageing in humans have been studied exhaustively, it is time we do the same for our green friends. They have provided us with so much, from food to medicine, it is time we explore their world and find some answers. The more we learn about them, the more we determine how ageing, competition, and other factors affect them, the better we will be at utilizing them. So, grab a notebook and pencil and watch some plants grow, because there is much to still learn.

References

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