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Creating a Multi-Berry Shrub via Cross Grafting

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ABSTRACT: Grafting is a process used to physically combine two different plants together. This process allows for a scion, the branch of one plant, to be added to the rootstock, the base of another plant. Combining plants allows for more varieties of fruit to be produced in less space for fruit bearing plants and creates more opportunities for hybridization with the plants utilized. Currently, research shows that grafting is possible when two plants of the same family are used. Using blackberry and raspberry plants, this study tests if the structural integrity of the rootstock can successfully support a scion from a plant of a heavier or lighter weight. This experiment also used common household tools to see if grafting could be affected by the quality of materials used. Overall, results showed that the rootstock, the grafting method, and the healing process were affected by the type of rootstock used, which in turn affected the success rate of the grafting procedure.

KEYWORDS: biology; grafting; botany; plant

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INTRODUCTION

Grafting, the process of inserting a cut branch or stem from one plant into a different plant, is a method that has been used often throughout the years. A reference to grafting goes back as far asAncient Rome. Romans used grafting with walnut and apple trees, they would graft new stalks onto previously barren trees via a process of combining a scion with the tree (Lowe, 2010). A scion is a branch or cutting from a plant that is taken and transplanted onto a branch or stem of a new plant, called the base plant or rootstock. This process can be used on plants of almost any age and size. The only limitation found so far is that grafting must be done with plants that are of similar genetic makeups and with plants from the same scientific family (Couts, 1910). The process of grafting is useful because it allows plants to produce a larger quantity of fruits and produce fruits that may not be able to grow on their own base plant in different environments.

In addition, grafting is used to help prevent product loss to disease and environmental stress (Bilderback, 2014; Qing, 2015). Depending on the method, growers can also use grafting to provide more benefits to the plant. For example, double grafting, which is the process of adhering an intermediate plant to a younger rootstock, is used to increase yield by grafting among the same species, this is exhibited with mango, a type of mango that has a good yield is grafted onto a base that has better resistance, in order to increase the overall net gain of the grower and increase the plants' survival rate (Singh, 1980). Grafting can also be used to optimize the amount of available growing space for urban growers. Along with an increase in development, there has been a corresponding decrease in green space available for plants. By using grafting, an urban grower can produce multiple kinds of fruit and vegetables by using fewer resources and requiring less space, as well as increasing the yield and durability of other combinations (Koepke, 2013).

A large amount of the overall research into the study of grafting has been done with fruit trees (Bar-Joseph, 2011; Das, 2000; Loehle, 1990; Ma, 1996; Shah, 2016; Singh, 1980). Grafting has been found not only to provide better fruit yields but also longer harvest times, increased disease resistance, and enhanced nutrient uptake (Lee, 1994). Many studies have compared different grafting methods along with pre-grafting procedures to see which method or treatment produces the most fruit yield to greater increase fruit production, and optimize the time and resources spent on the plant (Yildaz, 2003). With this background in mind, this study aims to increase the success rate of the graft on a plant by testing not the grafting method or a pre-treatment plan, but the rootstock's ability to support the scion and to heal the wound inflicted by grafting. Specifically, this study tests if the characteristics of the base plant can affect the healing of the graft onto the base plant. We focus on the healing of the graft, because, if the plant does not accept the scion and integrate it into the branch, the benefits of the graft will not occur.

To test which physiology will better support the scion, we utilized two different shrubs of the same family, one of which had a woodier stem to see if the sturdier base causes any change in how well the scion takes to the rootstock. We hypothesize that the hardier, woody stem will better support the scion during the healing process and the woodier base will provide a better environment for the graft to adhere to the rootstock.

METHODS

This study uses methods and materials easily available to assist everyday growers in replicating our experiment and using our research to graft their own plants. For our plants, we used two species from the *Rosaceae* family—*Rubus fruiticosus* (blackberry) and *Rubus idaeus* (raspberry). We started with three dormant *R. fruiticosus* shrubs and three dormant *R. idaeus* (Figure 1). The plant on the right is *R. fruiticosus* and the one on the left is *R. idaeus*.

Figure 1: Test Plants in Greenhouse. Photo credit Chelsea Schuler

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Both plants were under a year old at the beginning of the experiment and were kept in the University of Central Florida's public greenhouse. They were watered by a sprinkler system that rained water down onto the plants at set intervals. Because the greenhouse was a public greenhouse, the temperature and humidity changed depending on how long someone had the door open at a time. The grafting method used was cleft grafting—where an incision is made in a branch of the rootstock and the scion is inserted into the incision. In total, we grafted six branches between the six plants. To prepare the rootstock, we used a razor blade to cut a branch from each *R. fruiticosus* plant and each *R. idaeus* plant. The scions were then placed in water while unattached to a plant, and a 2.54 cm incision was made in the branch of the rootstock.

At the end of each scion, the outer tissue was sheared off to create a smooth, tapered end that was inserted into the cleft in the rootstock. One *R. idaeus* scion was attached to a corresponding *R. fruiticosus* rootstock and each *R. fruiticosus* scion was attached to a *R. idaeus* rootstock. Once the cambiums (the cellular tissue of the plant) of the scion and rootstock were aligned, the scion was inserted and the wound was sealed with wood glue before being wrapped in electrical tape (Figure 2). The wood glue and the electrical tape were placed over the wound to prevent water from entering the open graft.

Figure 2: Week one Hades Graft. Photo credit Chelsea Schuler

The scions were all the same length, about 10cm long, and placed toward the end of the rootstock's branch. When choosing the scions, we cut branches that were at the end of a side branch of each plant to ensure similar characteristics with the same chances for growth. The wounds were covered for three weeks, during which the height and welfare of the integument of the rootstock and scion were observed and recorded twice a week. After the three-week healing time, the grafts were uncovered, and the rate of healing and new tissue growth was evaluated. After the tape was removed, the health of the rootstock and the scion were monitored for an additional four weeks.

RESULTS

After three weeks of evaluation, the total growth rate of each plant and the health of the scions were evaluated (Figure 3).

The table shows the overall vertical height of each base plant and any buds that sprouted on the plant on branches without the graft. Of the rootstocks, the *R. idaeus* had a greater total height increase, but the *R. fruiticosus* plants experienced budding on their non-grafted branches (Figure 3). These buds were measured because, as they prospered, we saw the scion of the plant wither and dry out. Also, while the *R. fruiticosus* plants did not show a significant height increase, they did experience growth in new buds, causing their width to increase. This result provided evidence that while a scion was failing and dying, it was not due to the rootstock's health or lack of nutrients.

When the grafts were evaluated after three weeks, the scions showed new tissue growth at the site of the union on the *R. fruiticosus* rootstocks, but not on the *R. idaeus* rootstocks. Also, the scions on the *R. idaeus* plants were in much poorer health. We observed that the *R. fruiticosus* scions on the *R. idaeus* rootstocks did not have new tissue growth surrounding the initial cut. One branch did not even keep the scion in the cleft, and we could see the dried out inner tissue of the scion where it was sticking out of the cleft.

The *R. idaeus* scions on the r. fruiticosus, while still drooping and of a pale green color, did have new tissue growth surrounding the sight of the union (Figure 4). The scions on the *R. fruiticosus* rootstocks were also still soft to the touch on the leaves, unlike the scions of the *R. idaeus* base plants. One of the *R. idaeus* rootstocks lost its graft early in the healing process, for the side branch the graft was adhered to was found in the plants' soil

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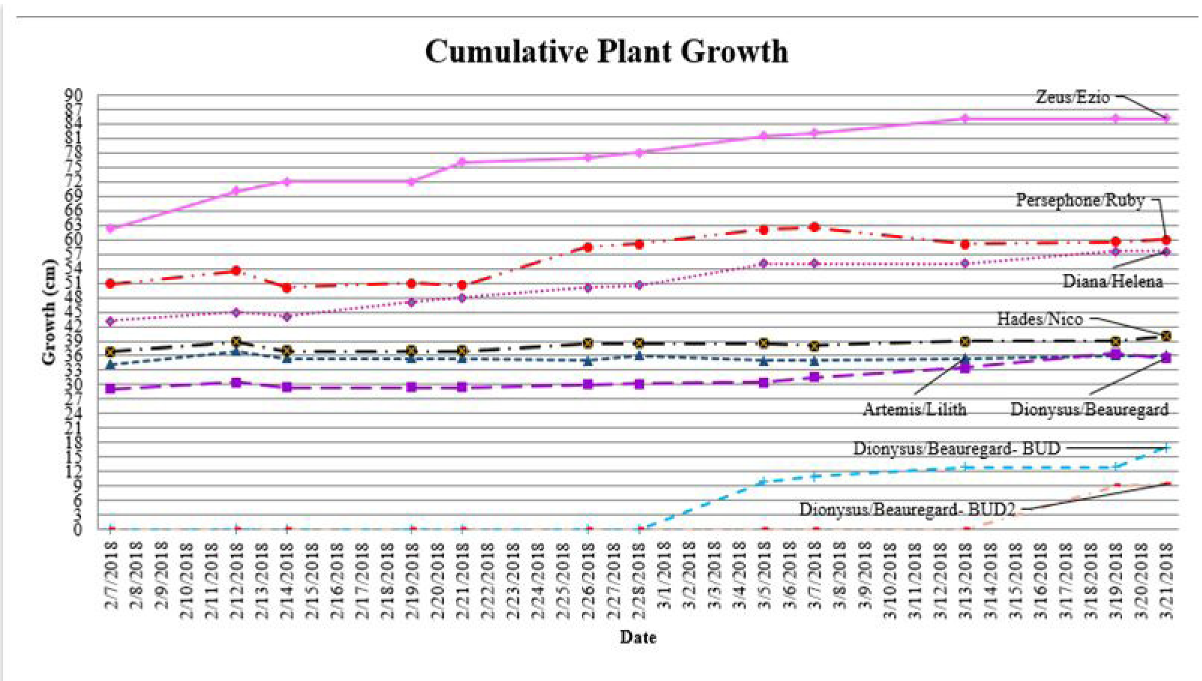

Figure 3: Rootstock Vertical Growth

after a night.

As the plant had dropped inefficient branches before, it is possible that the plant dropped the grafted branch as it did not provide enough benefit to the plant as another branch. Similarly, the graft on the *R. fruiticosus* plant, Dionysus, did not take to the rootstock, possibly due to the new growth the plant experienced in its new buds (Figure 4).

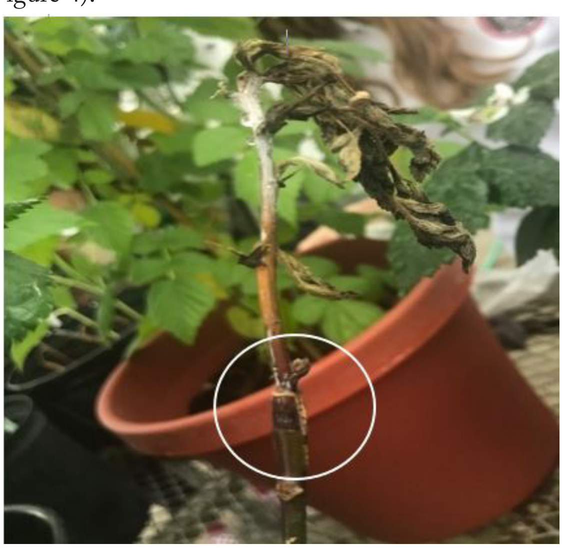

Figure 4: Week seven Hades Graft. Photo credit Chelsea Schuler

The remaining two *R. idaeus* stocks did not exhibit new tissue growth around the incision point when the tape was removed, whereas the remaining *R. fruiticosus* rootstocks showed new tissue growth surrounding the incision site. The scions on the *R. fruiticosus* rootstocks also exhibited healthier tissue along their stems, remaining a brown or green color similar to the rootstocks' branch color, while the scions on the *R. idaeus* rootstocks had turned brown, had shriveled, and had become brittle, losing most of if not all of their leaves.

These results are based on visual observations made throughout the experiment. During the first few weeks of the experiemnt, we saw the scions drooping on each of the plants and the leaves losing their vibrant green color from before the grafting process. During the healing process, in the second month of the experiment, we found that while the scions on the *R. idaeus* rootstocks were turing yellow or brown and becoming brittle, the scions on the *R. fruiticosus* plants were still showing signs of life though a soft, green hue. The scions on the *R. fruiticosus* rootstock were also found to be limp in support, but less dried out and brittle than the scions on the *R. idaeus* plants.

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DISCUSSION

The results of this experiment supported our initial hypothesis. There was a higher success rate among the rootstock with a hardier stem. The *R. fruiticosus* shrubs had a less sturdy stem (Figure 5) compared to the *R. idaeus* stems (Figure 6).

Figure 5: Raspberry Stem. Photo credit Chelsea Schuler

Figure 6: Blackberry stem. Photo credit Chelsea Schuler

The stems of *R. fruiticosus* did not bend easily and were darker in color. The shoots of *R. idaeus* were able to bend and contort as needed to reach upward to the sunlight and competed among themselves for resources. The stronger base on the sturdier *R. fruiticosus* showed signs of being able to support the scion to a higher degree, allowing a better chance for the tissues to fuse and nutrients to be passed to the scion. The *R. fruiticosus* plants could have also supported the graft, as they had been in a state or dormancy during the experiment. The dormancy state allows for less competition for the plant's resources during the healing stage, as the plant is conserving energy and not looking to optimize energy usage for growth at that time.

While the *R. idaeus* were also dormant at the beginning of the experiment, they exhibited a more opportunistic approach to their growth once they exited their dormancy stage. This growth style may have contributed to the grafts' failure to heal. Another factor that could contribute to a lower grafting success rate is when a plant drops branches that are injured, as is the case with *R. idaeus*; when a branch is deemed too costly by the *R. idaeus* shrub, it is quick to drop the branch. This mechanism is similar to how plants adapt when under stress or in difficult conditions (Gruntman, 2017). Plants, when in conditions that are harsh for growth, will adapt and redirect their energies toward growth types and features that suit the environment. This adaptation is seen in plants that grow in the shade of taller plants; they either adapt to growing in the shade or expend their energy on vertical growth (Gruntman, 2017; Bechtold, 2018). The *R. idaeus* plants grow multiple shoots at any given time, so they could have found that trying to heal the graft took more energy than growing a new shoot, and thus directed their energy to the most beneficial exploit (Karban, 2018).

While the lack of tissue growth over the union site could have been caused by the plant's decision, it could also have been caused by the scion being covered by the taller, uninjured *R. idaeus* branches, and thus being deprived of sunlight. Lack of sunlight can cause a plant to not be able to grow, hindering its development, and sometimes leading to death (Bechtold, 2018). Being hindered by taller shoots could have also contributed to the plant interpreting the branch as unbeneficial or caused the scion to not receive enough nutrients before it fully connected to the rootstock.

Another possibility is that the wood glue could have seeped into the plant's internal tissue, covering the vessels needed to transport nutrients to the scion and preventing healing from occurring (Bechtold, 2018; Kerr, 2019). Further study into grafting on a *R. idaeus* rootstock and altering variables such as the grafting method, pruning plants during the healing phase, or adding nutrients to the soil may show if there is a change in the success rate.

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As of now, further study into how different care methods can affect grafting success rates could further our understanding of this method and assist in making grafting more accessible to growers. This experiment used common household tools to see if grafting could be affected by the quality of materials used. In this instance, it is unclear if the wood glue affected the healing process of the graft, but the electrical tape was successful at keeping moisture from entering the wound. This method assists in making grafting more accessible to the public, such as Florida growers in an urban environment or arboretums at universities. In the city, there is not much green space and being able to optimize that greenspace while using easily-accessible materials can increase plant productivity and improve available resources. Grafting using common tools can also allow students to study grafting and to contribute to their community while going to school.

Although there are multiple grafting methods, this study chose to use cleft grafting to test the use of household items to graft an older plant (instead of a seedling) to have a better example of each plant's individual physiology. The study of the effect of plant physiology on grafting will be furthered by testing the use of household items versus grafting tools, cleft grafting versus grafting clip. We will also test to see if the age of the plant affects the plants' physiological effect on the process by testing seedlings and adult plants.

Overall, this study has shown that the rootstock, the grafting method, and the healing process can be affected by the type of rootstock used, which in turn, causes an effect on the success rate of the grafting procedure. With this result in mind our future studies will focus on narrowing down the extent that plant physiology affects the healing rate of grafting and if it is possible for the plant physiology to affect more than just the healing rate. Current research shows that grafting is only possible between related plants no matter the physiology. How closely related do the plants have to be is a question that can be further tested.

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