Optimization of Early Mangaba Growth

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1 Abstract:

The mangaba tree is an indigenous Brazilian fruit tree which is known for not only its fruit and rubber but also the difficulty of the cultivation. The fruit has a number of uses, the flavoring is used in alcohol, ice cream, and various other drinks and novelties. The purpose of this paper is to show that there are more efficient ways to cultivate the plant than the currently used processes. These processes come about from synthesizing numerous sources of data, which include optimal sugar levels, phosphorous levels, light levels, and acid and base levels, in order to properly optimize the early growth of mangaba trees. By taking numerous data points at different time intervals, it is possible to construct models, which are differential equations, which can accurately depict the general early tree growth over a short period of time. In addition to this data, the harvesting and storage of the fruit can be further optimized to yield longer times before the fruit spoils, making it more accessible and easy to transport from its native home.

2 Introduction:

Hancornia speciosa is a very delicate tree, because of this there are a lot of studies to try to improve the tree's life. Hancornia speciosa is currently harvested almost exclusively in Brazil, this is due mainly to the fact that the trade of seeds is largely prohibited in other countries, making the fruit difficult to obtain elsewhere.The fruit is also known for spoiling relatively quickly, so there has also been fairly extensive work in the harvesting and preservation of it, although not nearly as much as the more popular fruits. 86% of the fruit from the tree is purely pulp, and it is known for being quite nutritious.[1] Despite its commonly praised taste and texture, there are great difficulties when it is cultivated, as it is very responsive to environmental conditions. Unlike other fruit trees, mangaba requires high temperatures (around 25 degrees Celsius) and low amounts of rainfall (by many accounts, 750-1500 mm per year). Additionally, the plant grows best in sandy, loamy soil.[1] While these trees can also produce rubber when they reach maturity, it has been demonstrated that this rubber does not have as much tensile strength as most other rubbers, making it commercially nonviable for the most part.[4] Due to all of these factors, it is considered often not a viable tree to cultivate outside of its native environment.

Because it is so difficult to harvest, there are a surprisingly high amount of studies dedicated to furthering its growth, see [6], [8], [9], and [1]. The tree tends to germinate well during the first four days of being harvested [9] and that the tree has a very high germination rate when the soil has activated charcoal.[7] Another oddity of the tree's growth is that it tends to grow quicker when having a decent exposure to light during its first few days.[7] A number of methods have been proposed to quicken the early stages of the tree's growth. These methods typically only look at the first few months of the tree's growth – in part because it frequently takes 4 to 5 years to grow fruit, although it has been noted to grow faster or slower in certain cases.The goal of this paper is to minimize the growth period and determine the influential factors that cause the tree to mature faster. The methods, as briefly detailed in the abstract, include altering the amounts of sucrose and phosphorous put into watering the tree [9], changing the amount of light the tree receives, and changing the acid and base levels of the water as well [2]. Since there are so many parameters involved with modeling all of these in conjunction with each other, it is necessary to have a strong general model of the tree without these conditions. It is impractical to accurately model the tree growth under "normal" conditions, since these conditions vary depending on which type of tree is being planted, other chemicals in the water and dirt, etc.

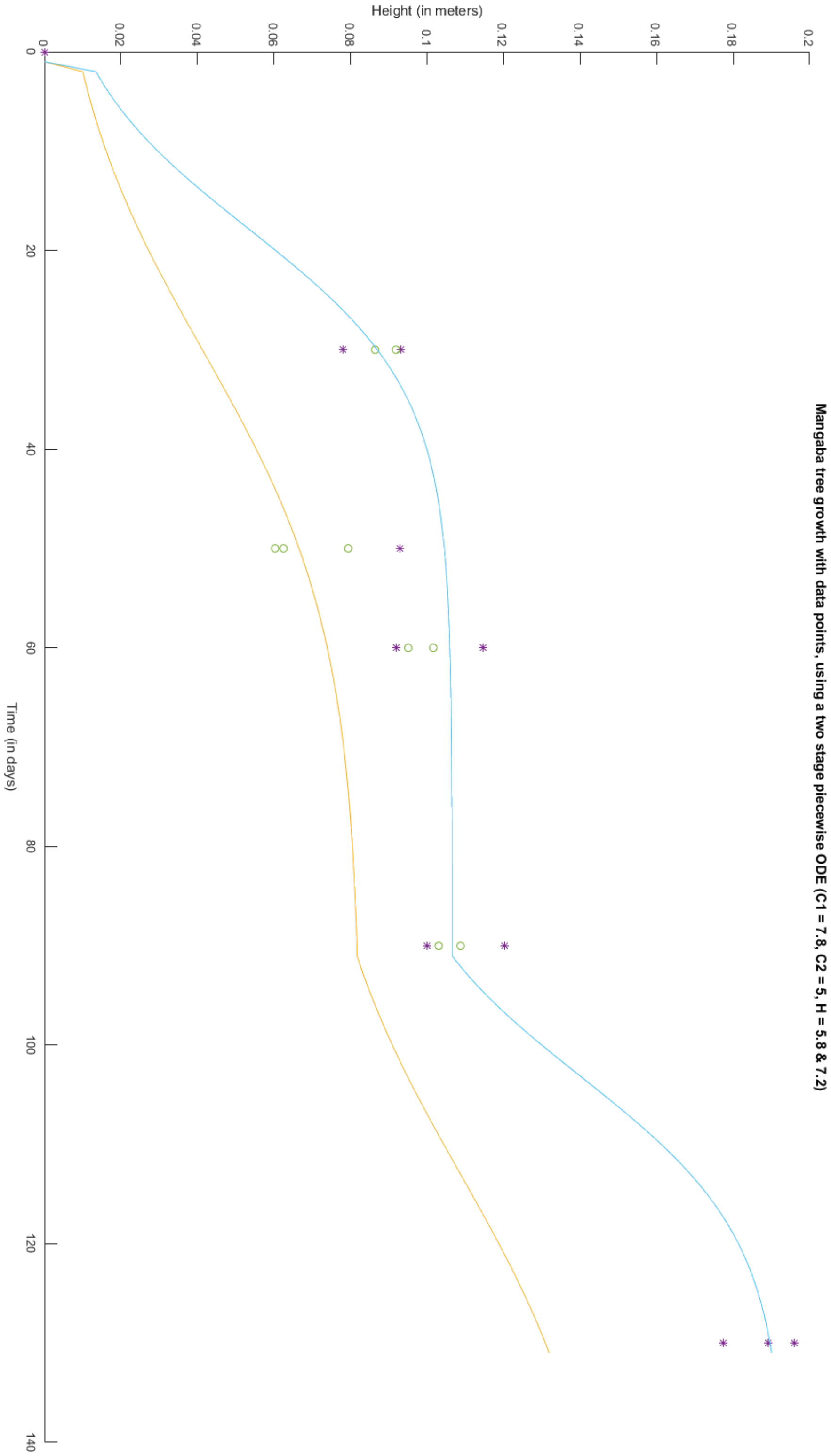
So far, there are no academic papers on using all of these methods together in order to fully optimize the tree's early growth stages and there are currently no known models on mangaba tree growth specifically, the goal of this paper is to address both of these issues, in one synthesized report.

3 Mathematical Approach & Contributions

As mentioned previously, there has been quite an extensive amount of research on the plant in different conditions. One such example of this is altering the amount of Mannitol in the water given to the plant during its early stages of growth.[2] Using the data from this with no Mannitol, a basic model was constructed. Notably, there was data for the height of the tree at 30, 60, and 90 days, giving a solid framework to the growth model. There were other models that had tree growth around these times and shortly after, so this data was added as well. For a general equation to model tree growth, the following was noted as a relatively straightforward equation for height over time.[5]

$$h(t) = \frac{C_2 H e^{kHt}}{1 + C_2 e^{kHt}} = \frac{H}{1 + Ce^{-kHt}}$$

Here, k represents its current height, H represents the maximum height (estimated to be 7.2 m) [1], t is time in days, and C is an arbitrary constant. After testing this formula with varying values of C, it was determined that this equation could not accurately model the results that were extrapolated from the Mannitol paper. However, it was found that the tree in fact had two growth cycles in its early stage, and the general ODE above could be used to model tree growth. It was found that the data could be mapped with two iterations of the ODE with time essentially "restarting" at the 90 day, phase, this was seen as the data seemed to stagger around 90 days and then jump to the next points. This was done to accurately model the data both before and after the 90 day period, using the 50th and 130th day data from another source [6] and [7] about seedling growth under various conditions The results are shown below:


Mangaba tree growth with data points, using a two stage piecewise ODE (C1 = 7.8, C2 = 5, H = 5.8 & 7.2)
Height (in meters)
Time (in days)
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
20
40
60
80
100
120
140

Here, as mentioned previously, H was 7.2, C1 was chosen to be 7.8 for the first piecewise function, and C2 was chosen to be 5, as these values seemed to match the given conditions most accurately. At this point, the model was considered to be accurate for mangaba tree growth for the first four months, with the C values being able to be altered for other conditions (such as sunlight the tree receives, the type of soil, etc.). Another H was chosen to be a somewhat arbitrary 5.8 in order to show that a poor mangaba tree could grow at a much slower rate in its early stages; which is somewhat consistent with the highly variable data. This also demonstrates what can happen when one of the constants is sufficiently modified.

It should be noted that it was impossible to quantitatively solve for the C values since they varied over time, and this was attempting to map a continuous function. For this reason, the C values were approximated and attempted to best fit the data, and exact precision was not necessary since there was so little data to go off of in the first place.

Through the model given above, it was possible to fit the curve to the applicable data points found in the Mannitol and sunlight based articles. Not all reports had data which coincided with this formula or data. For example, a certain report on in vitro mangaba in various mediums had data on the height of the plants at 50 days, and they were all shorter than those that were in regular water in an alternate report at 30 days, so this data was considered unusable since it was not optimized growth. [7]. As seen on the graph, it is also possible to change around the constants (H in this case) to fit certain data curves, such as the in vitro mangaba; additionally the C values can be changed to better match the optimal curve as conditions for the plant change (such as altering amounts of Mannitol, changing the light conditions, etc.) For the optimal growth in early stages of mangaba, one source discovered that the best fertilizer (which was, in some cases, as much as 100% more effective than others) was fertilizer with 33% bagasse, which is a fibrous matter that comes from sugar cane. [6] Since bagasse is relatively easy to afford, being about \$ 0.05 per pound [14], this can be seen as an optimal fertilizer for early growth of mangaba. This experiment did not tamper very much with other conditions, however, so the growth may be optimized further. In addition to this, it is well-known that the plant grows better under sunny conditions.[3] From the article on altering sucrose concentrations in the water, it was found that a low amount of Mannitol in the first month of development could contribute positively to the overall growth of the plant (around 6 g/L), and then using regular water throughout would give the best possible growth for the plant.

4 Conclusion

In terms of raw harvesting of the fruit, one study found that the best conditions for preserving both the fruit's acidity and vitamin C in addition to expanding its shelf life would be chilling the fruit from somewhere between 6-8 degrees Celsius; for short-term storage of the fruit a, few days to a week, this is likely the best environment for promoting growth. Additionally, the fruit over time in these temperatures retained most of the physical and chemical qualities of freshly picked mangaba. [10] However, it has been noted that there is a reduction of antioxidants whenever mangaba fruit has been stored for more than a few days, making it somewhat less appealing for this reason.[12] For more research in this area, it may be optimal to look at other conditions such as humidity and potentially freezing the fruit for long-term travelling.

For more future investigations, there is some data on the harvesting of the fruit itself, although this data is somewhat basic and could likely be expanded on. As an example, there has been some study into the respiration rate of plants with regards to temperature, although the main report which investigated this found fairly expected, linear rates of respiration (where in respiration rates increased as temperatures increased). This essentially means that putting the fruit in lower temperatures leads to a lower amount of respiration and therefore means that the fruit will take longer to spoil, which overall makes intuitive sense. [8] In addition, there has also been another study into preservation with pectin, they found that a 6 to 8% pectin biofilm seemed to increase the storage of the fruits. [13] There has not been a huge amount investigation in regards to late growth, and while it can be assumed that mangaba grow as any other fruit trees, such as oranges, there is little quantifiable data to back this up. Future investigations into experimental methods for the long-term growth would allow for the possibility of a more optimized model in the future (or simply different C and H values altogether). Since other trees have had their growth modeled over time with sufficient data, there is no reason to think that mangaba will be anything different. Overall, other than some very basic testing in its early stages, mangaba has not been subjected to repeated experiments or analysis outside of a couple of studies. For this reason, it is difficult to make sufficient conclusions about its best conditions until further research has been done. The above methods give a good groundwork for preliminary experimentation, but mangaba growth is likely severely underdeveloped due to the lack of solid information.

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