Predicting Pungency in Chile

New Mexico

Supercomputing Challenge

April 6, 2011

Team Number 48

Hatch Valley High School

Team Members

Joel Cazares

Selinda Garay

Teacher

Creighton Edington

Project Mentor

Nick Bennet

<u>Table of Contents</u>

List of Figures

Executive Summary

We are trying to model how chile pungency and yield is affected by the amount of water added. This is a continuation from last year's project. This year we have added height of plant, position of fruit, and many more variables into our program. We conducted additional research and had tremendous help from Dr. Paul Bosland, director of the Chile Pepper Institute at NMSU. Unfortunately the chile field that we planted last year to validate our program did not grow as expected, so we could not determine whether our program from last year was returning accurate information. To compensate, this year we compared the data that our program returned to some research articles, and we are also planning on planting a chile field this summer with the help of the Chile Pepper Institute to determine if the new variables added to our program are correct. If everything goes well we plan to distribute to the program to some local farmers who have shown interest in it. This way we are helping boost the economy and use of agricultural technology in our community.

Objective

Figure 1: Sack full of green chile

The goal of this project is to model how water, temperature, height of plant, position of fruit, and fruit length affect the organoleptic sensation of heat, or pungency, of chile peppers. Our computer program will be able to determine what the yield and pungency of chile peppers is depending on how the variables, mentioned above, affect the plant and the fruit. We would also like to be able to use the program to inform farmers that grow chile, about the pungency of their crop before the harvest. This will save them from conducting high-performance liquid chromatography, a time consuming and expensive procedure to determine the pungency of their crop.

Background and Research

Chile peppers are becoming more popular in the United States due to the fact that more people are using them in their cuisine or as decorations for their homes. The chile pepper's pungency is designed for protection against mammals trying to eat them. Mammals are the only living things who can feel the heat of the capsaicinoids which make the peppers hot. The main reason why we are interested in doing research on this specific subject is because we have been living in Hatch, New Mexico all of our lives. Chile is an important part to Hatch's economy and lifestyle. We, like the majority of the world, wonder what makes a chile hot. As chile continues to grow more popular in our society, people want to know how the chile pepper gets its pungent taste and what factors contribute towards its pungent flavor.

The pepper fruit contains many chemical compounds known as capsaicinoids which give the fruit its pungent flavor. The most common components of this class are capsaicin and di-hydrocapsaicin. Together they make up 75-85% of the capsaicinoids found in chile. Capsaicinoids are not soluble in water, but they are very soluble in fats, oils, and alcohol. Pure capsaicin is rated at 15-16,000,000 SHU, which stand for Scoville Heat Units; the units of measure that tell how hot a chile is. "All capsaicinoids found in chiles are slightly different in their hydrocarbon tail. This difference allows them to penetrate and bind to nerve receptors in the tongue, mouth, and throat. This explains why some chiles burn in the mouth, while others burn deep in the throat," (http://ushotstuff.com/Heat.Scale.htm).

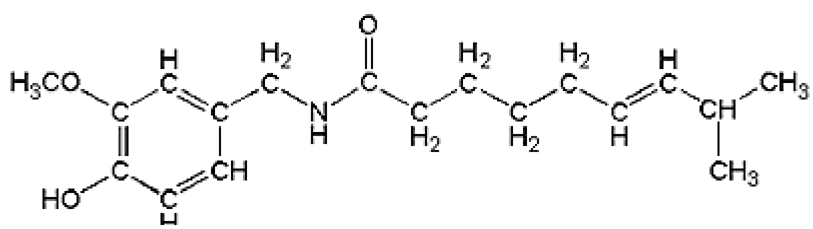


Figure 2: Molecular diagram of capsaicin.

Chile plants may become more or less pungent if they are stressed. Two types of stress that affect the pungency of peppers are having a high average temperature outside, and insufficient watering. Another form of stress is overwatering. It does not matter what type of stress the plant goes through; any type of stress will increase or decrease the pungency of the fruit. This is one of the main reasons why the majority of farmers do not like to over water their crop.

Many experts disagree on what factors affect chile. There have been a lot of studies conducted on how the chile plant is affected by the different factors. One study, *Pungency of Chile Fruit is affected by Node Position,* talks about how the position of the node, the area of a plant's stem from which the leaves grow, and how it affects how pungent the chile will become (Zewdie 2000a). This article also states that fruits grown on the second node, from the base up, will average a higher pungency than those on the fifth or sixth node. Another study explains how the pungency of the fruits on a single plant can differ in their pungency levels (Kirschbaum-Titze 2002). This means that out of all of the fruits on a chile plant most of them will not have the same pungency. Fruits from one side of the plant may be under a different type of stressor than a fruit on the opposite side. Other studies have demonstrated that the amount of capsaicinoids in the pepper fruit fluctuates as the fruit is maturing. Some articles even suggest that "capsaicinoid production increases with maturity and then reaches a peak, followed by a rapid degradation of up to 60%" (Iwai 1979). It is very difficult to try to model the amount of pungency in a chile pepper at a given time due to all of the factors that determine what the total pungency will be in the fruit. However by conducting the appropriate type of research, we are able to create a program that may benefit

Figure 3: Example of a node

farmers at the end of the season. This way they do not have to rely on the seed variety alone to determine the pungency of their crop.

A Spicy Life: Farming Chile


Figure 4: Picture of a chile field.

In order to fully understand when the different factors affecting chile begin to take effect, we interviewed several farmers and asked them about the typical growing process of chile. The chile pepper season begins with the farmer preparing the soil on the farm. They create furrows and ridges and test the soil for necessary nutrients that chile plants need in order to thrive. Two of the major nutrients needed for chile peppers to grow are nitrogen and phosphorus, which are necessary for growth and protection against disease. The most common row width, that farmers in the area surrounding Hatch use, is 36 to 40 inches. Many studies have shown that less space between the rows can result in a more pungent fruit, however yield will decrease dramatically. Today farmers are more interested in the amount of yield they produce and not the overall pungency of their chile. The more the field yields the more money the farmer will make. Many small scale farmers would like to grow chile with a high pungency without having to sacrifice yield. On the other hand, many farmers who sell the majority of their crops to a chile processor do not really care about the pungency, because they are interested in the yield.

Once the soil is prepared for planting the farmers begin to irrigate the field, making sure that the soil has enough moisture for the seed to grow. Most farmers begin applying water to the field 5-7 weeks before they begin to plant. The usual planting date in southwestern New Mexico is between March 1 and April 1. After the seed is planted the temperatures should not drop below 60˚ and should not exceed 90˚. The plant can die or the growing process will stall from a light frost or excessive heat.

To irrigate their crop farmers usually have to work with the amount of water that Elephant Butte Irrigation District gives them for the year. This is what determines the irrigation cycle that the farmer will use for the crop. The irrigation cycle is the amount of time a farmer lets pass before watering the crop again. Usually farmers flood irrigate the field and apply water at 5-7 day intervals between June and July, before the monsoon season. They then switch to 7 or more day intervals, during monsoon season depending on rainfall amount. If all goes well the early green chile crop will be ready for harvesting about 130 days after planting or 35-45 days after flowering. The red chile crop will take another month to ripen before harvest.

Many other experiments were done in Thailand that show that the total pungency amount of the medium and mild chiles increase dramatically when put under stress. Usually mild chile will become medium chile, and medium chile will become hot chile when undergone by stress, but whenever it comes to hot chile the capsaicin amounts will show only a small amount of increase. This helps to prove that New Mexicans are not the only people who want an answer to the ultimate question, red or green?

Our experiment will try to determine how the pungency of chile is affected by environmental factors such as temperature and the amount of water added to the crop. There has not been an extensive amount of research done on how the pungency of chile is affected by these environmental factors. This lack of data proves to be a problem for our program. The program needs a sufficient amount of input to make it work efficiently and to obtain accurate output. Dr. Paul Bosland from New Mexico State University has been a great source of help with the direction of the research. He has been working around chile peppers all of his life and was one of the main reasons why we are still doing this project.

Back in November we visited MA and Sons, a local chile processing plant, and spoke to its owners about our project. We wanted to know what they thought about the project and if they had any suggestions for us on what to do with our program. During the meeting the owners of MA and Sons told us that our project had no real world value to it because farmers relied on the seed variety to tell them how hot the chile would be. We then managed to contact Dr. Bosland at the Chile Pepper Institute and he told us the complete opposite of what the owners of MA and Sons had told us. He said that our project would help out a lot of farmers worldwide. He gave us the following example,

> Suppose you are a chile farmer and you have 10 acres of farm land. You are going to plant all 10 acres of chile with a mild pungency and sell it to a local processing plant. During the season though the temperature is very warm and you do not water the plant enough. At the end of the season you will not have mild pungency chile, because the plants have been stressed so the chile peppers will have a medium pungency, meaning that you will actually be selling a chile heat level that the processing plant may not need or want. So by having a computer program that can tell the farmer approximately how hot his crop is, they would benefit a lot because they would not need to use high performance liquid chromatography to determine the pungency of the chile.

Materials and Methods

The chile peppers that the program will be based on are the Bell Pepper, Piquin, Jalapeno, and Sandia. To create the computer program we have gathered data from all types of sources. Most of these sources were online articles written by scientists or students who are interested in chile peppers. One of the most vital sources of information that we collected was an article published by the Chile Pepper Institute titled *Yield and Quality of Trickle Irrigated Chile*. This article described an experiment done by P.J. Wierenga that studies how water affects the chile's yield and its pungency.

In order to be able to work with the data, we had to convert the measurements into Scoville Heat Units. Most of the studies were all measured in g/mg of capsaicin. In order to convert all the measurements we talked to Dr. Bosland to determine how to convert g/mg of capsaicin into SHU, Scoville Heat Units. To convert mg/g to SHU, you need to know that 1 mg/1g is equal to 1000 parts per million (ppm). You need to multiply the ppm by 16 to convert everything into SHU.

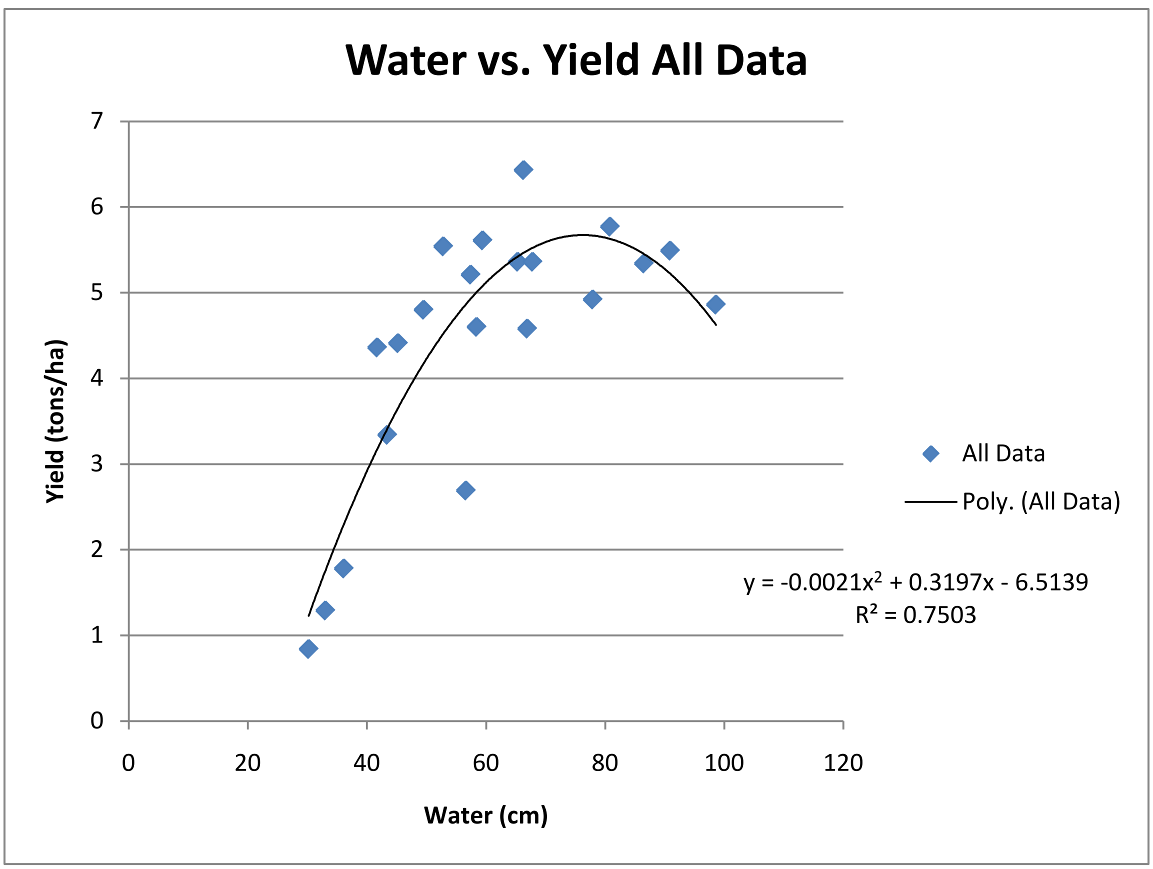
To covert mg/g of capsaicin into SHU use this formula

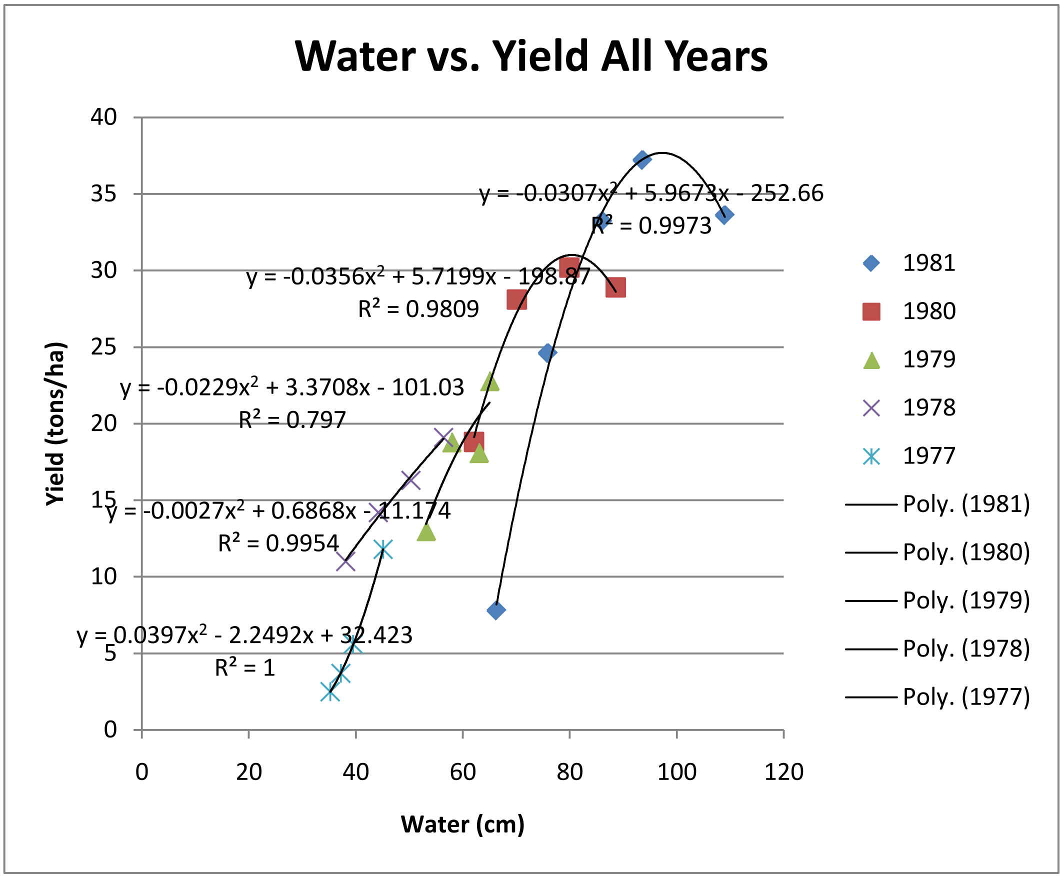
1g / 1mg = 1000 ppm

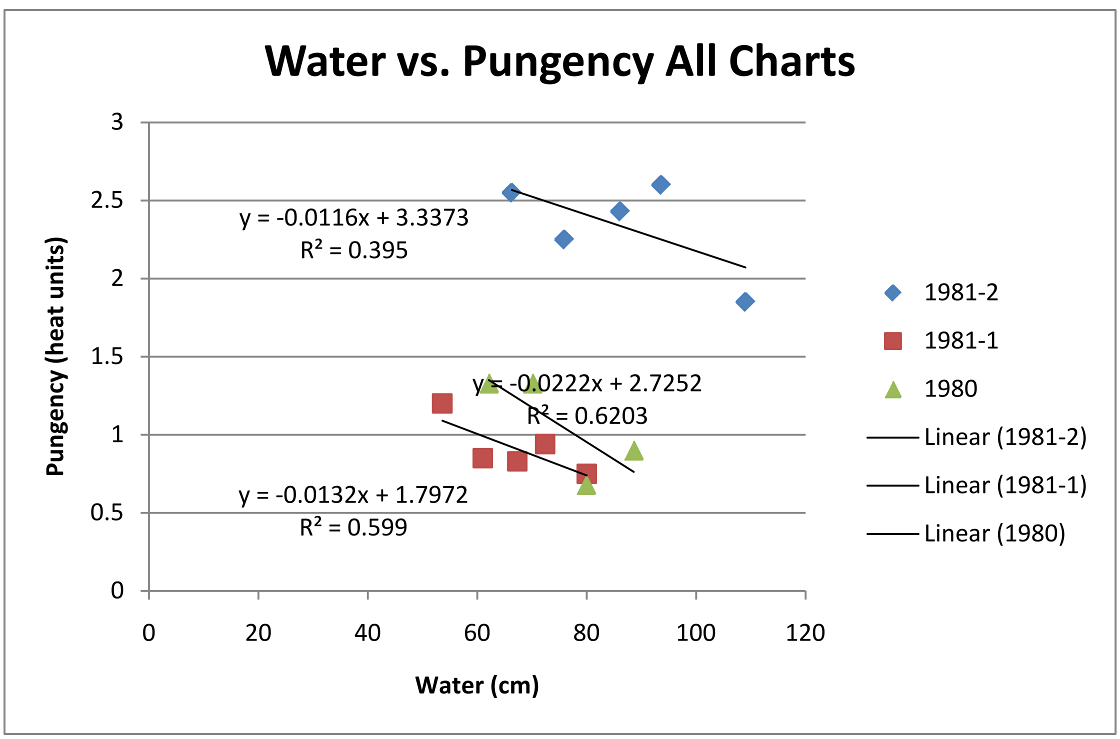
16 x ppm = SHU value

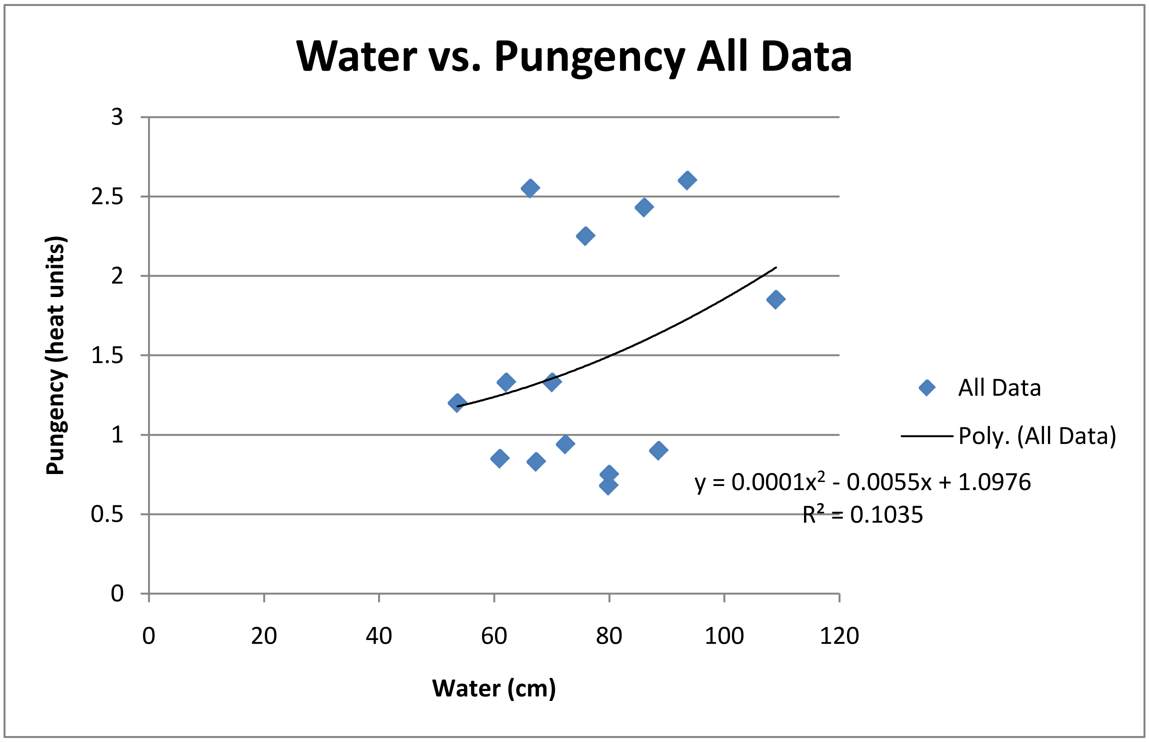
After we had all of the data converted, we began to create graphs using Microsoft Excel. We analyzed the graphs to determine if there was any correlation between any of the factors. We noticed that the pungency of the chile is inversely proportional with the yield. If the chile peppers were hot the plant did not give as much fruit as in a mild chile. The amount of water given and the pungency of peppers are also inversely proportional. The more water was given the less pungent the chile is.

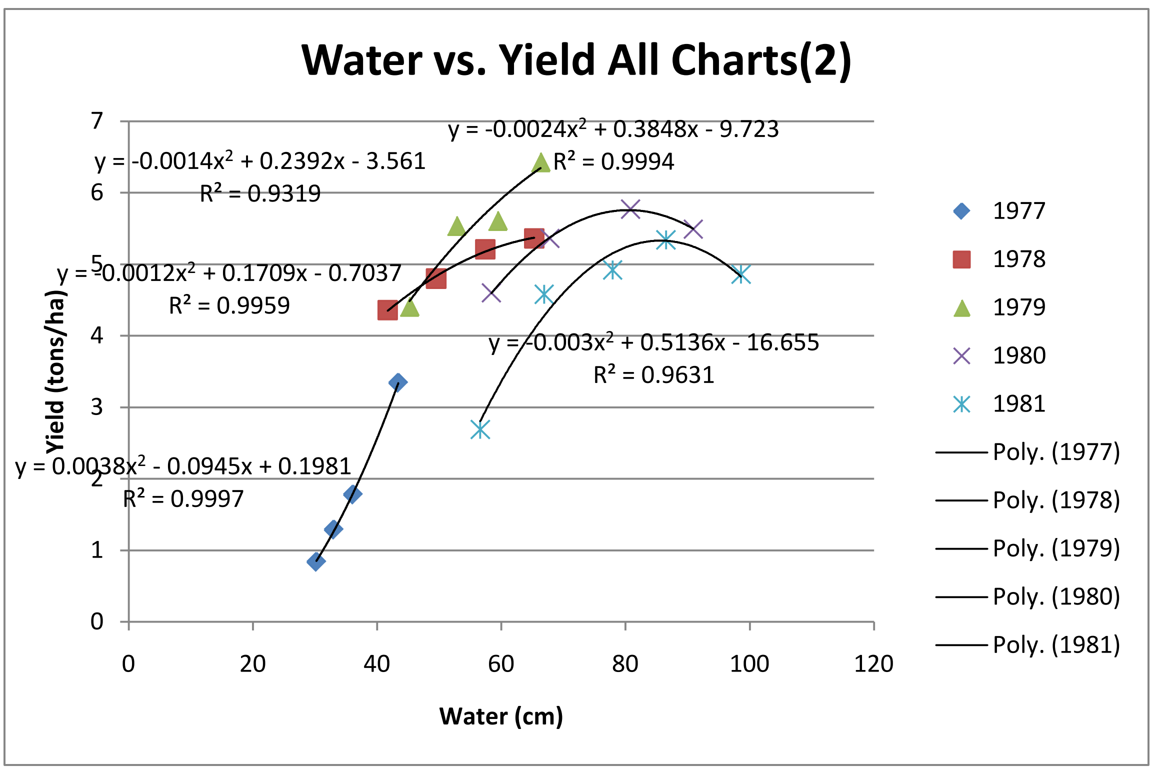
When all of the graphs were completed, we added a best fit curve to be able to get the equation of the line and the R^2 value. We did this because we did not have much data that compared the amount of water to the pungency of the chile. The R^2 value is the probability of having the next data point on the line. With the R^2 value we could determine where the next set of data points would fall on the line. The closer the R^2 value is to 1, the higher the probability of having the next data point on the line.




Water vs. Yield All Years
Yield (tons/ha)
Water (cm)
y = -0.0307x² + 5.9673x - 252.66
R² = 0.9973
y = -0.0356x² + 5.7199x - 198.87
R² = 0.9809
y = -0.0229x² + 3.3708x - 101.03
R² = 0.797
y = -0.0027x² + 0.6868x - 11.174
R² = 0.9954
y = 0.0397x² - 2.2492x + 32.423
R² = 1
40
35
30
25
20
15
10
5
0
0
20
40
60
80
100
120
1981
1980
1979
1978
1977
Poly. (1981)
Poly. (1980)
Poly. (1979)
Poly. (1978)
Poly. (1977)


Water vs. Pungency All Charts
Pungency (heat units)
Water (cm)
y = -0.0116x + 3.3373
R² = 0.395
y = -0.0222x + 2.7252
R² = 0.6203
y = -0.0132x + 1.7972
R² = 0.599
3
2.5
2
1.5
1
0.5
0
0
20
40
60
80
100
120
1981-2
1981-1
1980
Linear (1981-2)
Linear (1981-1)
Linear (1980)


Water vs. Pungency All Data
Pungency (heat units)
3
2.5
2
1.5
1
0.5
0
0
20
40
60
80
100
120
Water (cm)
All Data
Poly. (All Data)
y = 0.0001x² - 0.0055x + 1.0976
R² = 0.1035

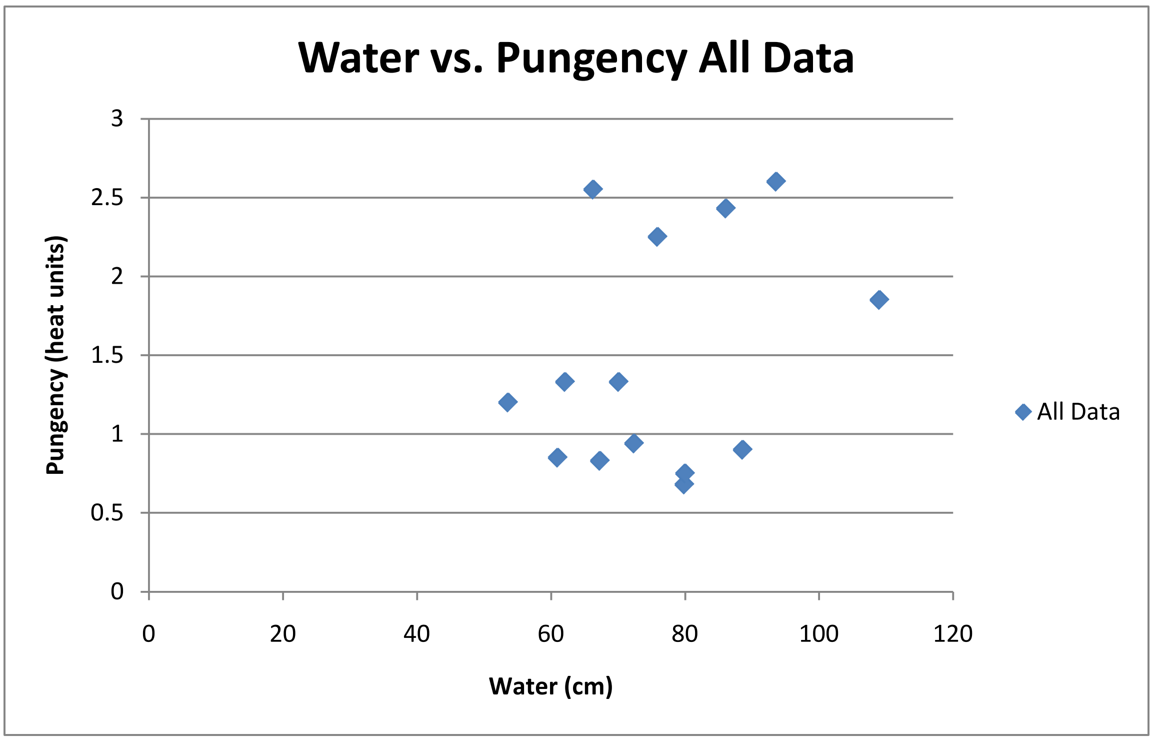

Water vs. Yield All Charts(2)
Yield (tons/ha)
7
6
5
4
3
2
1
0
0
20
40
60
80
100
120
Water (cm)
y = -0.0024x² + 0.3848x - 9.723
R² = 0.9994
y = -0.0014x² + 0.2392x - 3.561
R² = 0.9319
y = -0.0012x² + 0.1709x - 0.7037
R² = 0.9959
y = -0.003x² + 0.5136x - 16.655
R² = 0.9631
y = 0.0038x² - 0.0945x + 0.1981
R² = 0.9997
1977
1978
1979
1980
1981
Poly. (1977)
Poly. (1978)
Poly. (1979)
Poly. (1980)
Poly. (1981)

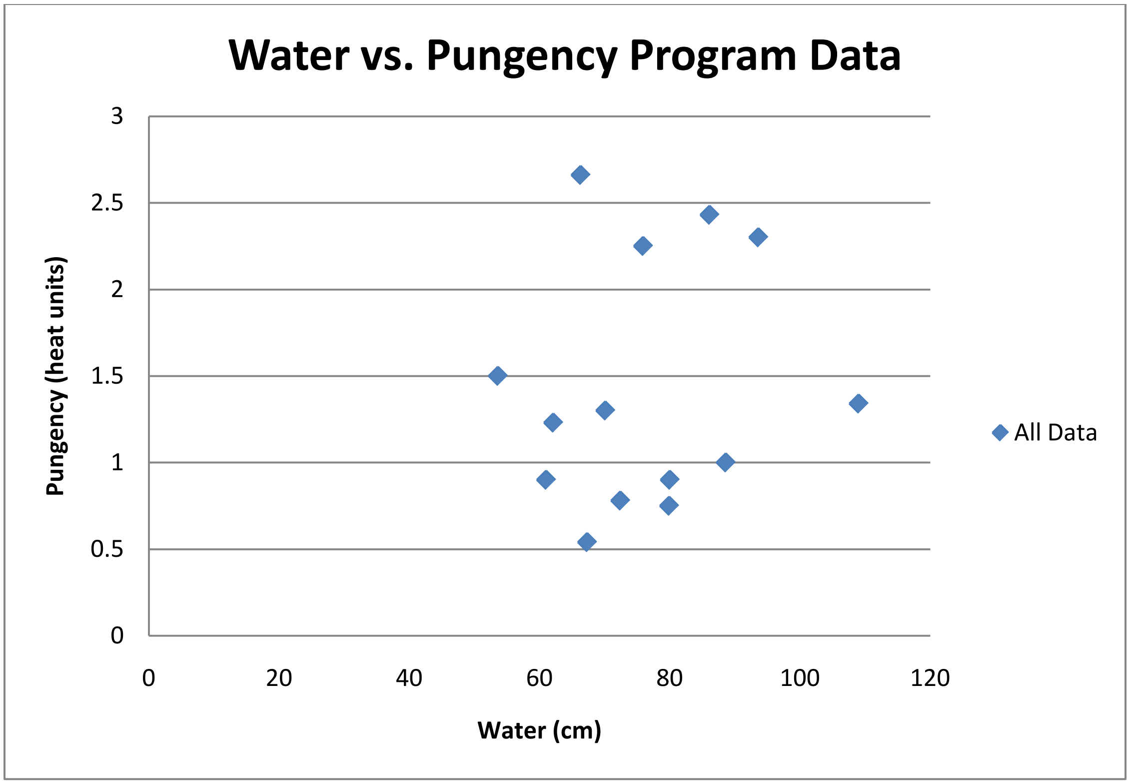
We also used the equations and the R^2 values generated from the Excel graphs, to add randomness to the program. This was done by choosing the equations that graphed pungency against amount of water added, and had an R^2 value closest to 1. We added all of these equations to the program and then let the program decide which equation it wants to use, to determine the pungency of the plant being modeled. We decided to do this because we noticed that many other programs just used ± 10% as randomness. We wanted to try a newer method of randomization so we picked this method. This way the results will never be the same twice.

After we had all of the data and had completed the program, we decided to include more variables into the program. The variables are height of plant, position of flower, and fruit length. This data came from Dr. Bosland and the article by P.J. Wierenga. We had to do some extra research on how the different chile types grow. It did not take us long to come across a study that explained that most chile varieties all grow the same. This came to our aid because due to this we did not need to add any type of randomness to this part of the program.

Results and Analysis

After running the computer program many times, we gathered the data output and graphed it against the amount of water and hoped that it looked like the graphs we had made using data from the article by Mr. Wierenga. Thankfully there was not a lot of difference between both graphs




Water vs. Pungency Program Data
Pungency (heat units)
3
2.5
2
1.5
1
0.5
0
0
20
40
60
80
100
120
Water (cm)
All Data

Conclusion

After running the program many times we have noticed that it always returns an SHU (Scoville Heat Units) value that seems reasonable. Based on the data that the program returns and how it compares to the data that we gathered, we know that it is returning accurate pungency outputs. We are planning on teaming up with the NMSU Chile Pepper Institute and plant a field of chile to see whether the outputs for the remaining factors are accurate.

Acknowledgements

We would like to thank all of the people who helped us accomplish this project especially Mr. Edington, Mrs. Torres, Ms. Weiler, and Mrs. Harvey. We would also like to thank Nick Bennet and Christy from UNM. Special thanks go to Dr. Bosland and all of the people at the Chile Pepper Institute. Finally, we would like to thank Governor Susana Martinez for taking the time to talk to us about our project, on April 5, 2011, the day she signed the Chile Advertizing Act.

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Zewdie Y., and P.W. Bosland. **2000a**. Pungency of chile (*Capsicum annuum* L.) fruit is affected by node position. HortScience. 35: 1174.

Many blessings in all you do! Susana 4-5-11

Appendix A: Code

```
globals
[
yield

row
SHU1
SHU2
total-SHU
i
]

breed [ chilies chili ]

chilies-own [ SHU ]




to setup
 clear-all                                ;; clears and resets all previous things within the world
  set SHU1  ( -2.3035 * amount-of-water-start + 1037.9 )
  set SHU2 ( 13.471 * amount-of-water-start )
  set yield ((0.0029 * amount-of-water-start ^ 2) + (0.1243 * amount-of-water-start))
  field
  rows
```

```
  while [ i < 909 ]
   [
    ask chili i
    [set total-SHU total-SHU + SHU]
    set i i + 1
   ]
  set i 0
end



to go
set yield yield + ((0.0029 * amount-of-water-added ^ 2) + (0.1243 * amount-of-water-added))
ask chilies
 [
 set SHU (SHU + (-6.1952 * amount-of-water-added ^ 2 + 246.46 * amount-of-water-added -
     827.92))
 ]
 while [ i < 909 ]
   [

    ask chili i
    [set total-SHU total-SHU + SHU]
    set i i + 1
   ]
```

```
    set i 0

end



to field
ask patches
  [
    set pcolor brown
  ]
end



to rows
    ask patches
    [
      if (pxcor = 10 or pxcor = 20 or pxcor = 30 or pxcor = 40 or pxcor = 50 or pxcor = 60 or
            pxcor = 70 or pxcor = 80 or pxcor = 90)
      [
        sprout-chilies 1
        [
          set shape "plant"
          set SHU one-of (list SHU1 SHU2)
```

```
      set size 1
      set color green
     ]
    ]
   ]
End
```