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# The Effect of Climate Patterns on Fruit Ripening Near Lincoln, Nebraska

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by

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## Abstract

The research for this project was conducted at an orchard 12 miles north of Lincoln, Nebraska. The climate data came from the far north side of Lincoln, Nebraska. This study used a mixed methods approach to combine quantitative and qualitative data retrieved. The purpose of the study was to come to conclusions as to where fruit ripening patterns and production can look for the future, to bring about an estimation of fruit ripening patterns based on climate to help stimulate more production and efficiency for businesses and because knowing what climate trends will allow for new growth in Nebraska down the road has a big potential production value. The question being investigated was, "What effects will a higher minimum temperature in winters, varying start/finish/lengths of growing seasons and similar changing climate patterns have on fruit ripening patterns in Nebraska?" My proposed hypotheses were that there have been higher minimum temperatures which allow more varieties of fruit in northerly locations, an earlier start to the growing season would mean an earlier harvest, an earlier end of the growing season would mean an earlier harvest or smaller harvest and a longer length of growing season would mean harvest would be further from the start of the growing season. Samples of several peach and apple varieties were collected and the date of ripening was recorded for 2013 and 2014. Climate data was analyzed for the timing of the growing season, along with year round minimum and maximum monthly temperatures and minimum temperatures for winters for the past 40 years and back to 1887 for trends with future projections. With a comparison of climate trends and fruit ripening dates, it was found that increases in February temperatures has the biggest effect on when trees will be ripe in the summer and fall. A warming in February will start the reproductive cycle of the tree earlier. Trends in warmer February temperatures means there will be earlier bud breaks in the future, while April minimum temperatures dropping means there is a higher chance for buds and/or blooms to freeze and hurt production in the future.

## Preface

*A special thanks to Dr. Ken Dewey, Sara Cooper, Dr. Dave Gosselin, Leon Page and Dale Lilyhorn and Martin's Hillside Orchard*

## Introduction and Literature Review

Studying the changes in hardiness zones and dynamics of growing season in the United States, and more specifically Nebraska, is important in understanding the effects on the growing of peaches, apples, and the potential for many other fruits and produce. Hardiness zones are defined as the average lowest temperature an area reaches over a 30 year period of time (USDA 2012). In order to understand the changing implications of these zones and the future effects on agriculture, one must look at who it affects, how it affects them, problems that may arise and phenomena that may arise from these changes. This is worthy of research because of the wide variety of individuals and groups it has, can and will affect. With changes in hardiness zones, come changes in what companies and individuals can raise in particular areas. Mapping out these changes and picking trends for the future has the potential to bring about the correct innovations. I looked at how changing hardiness zones, average, maximum and minimum temperatures and varying starts, ends and lengths of growing seasons are affecting fruit ripening in the areas surrounding Lincoln, Nebraska. This is important for present and future production of apples, peaches and other fruit types near Lincoln, Nebraska, along with applications to areas with similar trends in climate.

The changes in hardiness zones have been noted by the USDA over the past fifty years. Hardiness zones are based off of average annual low temperatures over a 30 year period of time (USDA 2012). There are 10 major zones in the United States and two sub categories for each zone. The sub categories are “a” and “b”. The 10 zones are divided in 10 degree increments of annual average lows. The sub categories are in increments of 5 degrees. Lincoln, Nebraska was in zone 5a from 1974 to 1986, which is an average annual range in low temperature of -20 to -15 degrees F.

With the times and climate changing, Lincoln, Nebraska in 2012 has been bumped up to zone 5b, which is an annual range in low temperatures of -15 to -10 degrees F (USDA 2012.) Other displays of changing hardiness zones can be seen by the fact that less than half of the state of Nebraska was in zone 5 in 1990 and now nearly all of Nebraska and parts of South Dakota are in zone 5. This pushes vast portions of the state from

plants that can survive in annual ranges in low temperatures of -30 to -20 degrees F to -20 to -10 degrees F. The raising of minimum temperatures is significant because lower temperatures in the months prior to harvest increase susceptibility of fruit to breakdown (Martin 1954). Another reason it is significant is that a plant's ability to avoid injury is severely affected by the minimum temperatures during the winter (Quamme 1976).

The importance of these changes can be seen readily by the introduction of new wineries into the state over the past 15 years. James Arthur Vineyard was the second winery in the state of Nebraska in 1997 and there have been at least 15 additional wineries in the state since then (UNL 2007). The main cause in the rise of wineries has been the fact that grape vines are not dying back to the roots over the winters and they can then thrive more on a yearly basis. With average annual low temperatures not as low as they have been in the past it has been recognized that a business in grapes is potentially profitable and others have followed along. One implication of a study looking into the future of hardiness zones and growing seasons for a specified area, is that trends can be used to see what the next great fruit produce in Nebraska may be. If a study shows that Nebraska is a good place for a new variety of fruit in the next 10 years, then a farmer can get a jump before the time has come and establish the proper network and requirements for the new big thing.

It is also important to look at a changing climate and the response of plants. Plants have adapted to changing climates across the globe for as long as plants and climate have both been around. The climate changes slowly and the plants have time to adapt or else die out if they can’t handle the changes. Recently there have been many more rapid changes than in the past and it is being looked at as to whether plants will be able to handle it. One problem that comes with a rapidly changing climate is the introduction of new pests and disease outbreaks and plants responses in different areas (Jump and Penuelas 2005). Fruit trees are very susceptible to pests and diseases and an introduction of either unexpectedly can be detrimental to orchards. Mapping out these changes in climate is very important for orchards in Nebraska to see where future trends may lead us.

By looking at how changing hardiness zones and the lengths of growing seasons year to year will impact the production of fruits in the area surrounding Lincoln, Nebraska, one can apply findings to any number of

local causes. Farmers and residential growers can apply knowledge to what trees to plant for the future years to come. They may also be able to see which varieties are more likely to thrive in conditions year to year. This knowledge is very important in planning because most fruit trees that are planted won't bear fruit for several years and knowing what lies down the road helps to know what to do in the present time. From a business perspective, it is also important to know what each year may bring. If a year has a late start to the growing season it is very crucial to know which trees will be affected most by this occurrence in nature. Playing a guessing game in a business is necessary at times, but the less guessing the better. If trends in growing seasons related to changes in hardiness zone changes can be depicted, then one can begin to see what may happen in the fall as soon as the spring temperatures begin to rise. This is a huge advantage in planning around when harvesting may be, so that other business related expenses and activities may be accounted for.

One researcher found a method for acoustic testing of peaches that are being stored by looking at elasticity and firmness. This method could have been applied to testing the ripeness of the fruit on the trees for a standard. It was found the firmness and elasticity decrease over time and when the fruit is overripe it would be shown by the acoustic impulse response (Gomez 2005). This required more expensive equipment and it doesn't take into account the taste, sweetness or feel of the fruit for purposes of the proposed thesis. The methods used for testing fruit ripeness in my experiment will be better explained in the materials and methods.

It should be understood that there is a change in the climate system in one way or another. Different areas of the country are affected differently along with different seasons of the year for each area of the United States. A general rise in the global temperature has been seen (Hansen et. al. 2010) and this is again shown by the hardiness zones moving north around the entire country. How Lincoln, Nebraska is affected by all of this has been noted over the last century by climate data, which can be analyzed and associated with data for given ripening of fruit trees year to year and with trends coinciding with climate fluctuations over the past 30 years. Previous studies viewed show that there has been a direct correlation between climate and fruit ripening (Bertin 2007). I believe that trends can be depicted from climate data from the last 30 years that will show substantial

evidence of changing hardiness zones and changing lengths of growing seasons being in harmony with changes in fruit ripening durations and their ideal times for picking.

Looking at phenology and climate change is an important aspect in understanding variability in how plants will react yearly to changes in global climate and global weather patterns. Maximum temperature was the main variable affecting leaf unfolding (bud break) and spring flowering in a Mediterranean locality (Gordo and Sanz 2005). Summer fruiting was not related to maximum temperature directly, but there is a relationship between the time of flowering and summer fruiting. Experimental warming of plants advanced flowering and fruiting phenology for species that began to flower before peak of summer heat, but delayed reproduction in species that started to flower after peak temperatures (Arnone et. al. 2006). This study was simulated to represent fruit trees on a tall grass prairie in North America. The warming induced divergence of flowering and fruiting towards the two ends of the growing season and resulted in a gap in the staggered progression of the community during the middle of the season. The greatest response was by species flowering in mid-summer (Arnone et. al. 2006).

Bud break is when the tree starts the reproductive cycle in the early spring. When the maximum temperatures in late winter and early spring start to rise, they raise the root-zone temperature. This allows sap and nutrients to begin movement in the tree. This triggers bud swelling and an eventual break as the leafs begin to unfold from the bud. A study on Braeburn (*Malus Domestica*) apple trees found that 15°C was the approximate root-zone temperature threshold to start the moving of sap (Greer et. al. 2005).

A mixed method approach uses both quantitative and qualitative data collection to get conclusions from a study. The advantage of quantitative data collection is the absolute values you find and the ability to make charts and graphs with those exact values. The disadvantage can be the limitation of data that has been marked down exactly. The advantage of qualitative data collection is that the knowledge and personal experiences of those that did not record exact measurements can be brought to the eyes of others. The disadvantages can be the

accuracy of statements and the lack of exact values. The two study types cohere perfectly for this study in bringing to life the exact climate values and the knowledge of experts in the field.

My study looked closely into the direct effects of changing climate and year to year weather patterns on plant fruiting in the surrounding area of Lincoln, Nebraska. It has been shown by USDA that hardiness zones have been moving north. There has also been a direct linking of climate patterns to the ripening of fruit. It has also been found that maximum temperatures are the biggest influence on leaf unfolding. Knowing when fruit will be ready and when crops may be ready to pick, has beneficial production implications. Limitations were predicted to come from the locating of data on fruit ripening in the past 30 years. I had two falls to collect data first hand and to see how changing hardiness zones and climate patterns will be affecting the ripening of fruit trees.

## Materials and Methods

Throughout the summers and falls of 2013 and 2014 I looked at climate data and different times of fruit ripening. There is an orchard 12 miles north of Lincoln where I recorded the ripening of apples and peaches based on when they were ready to pick. The apples were cut open to see how dark the seeds were. For both apples and peaches other methods such as, firmness, taste, and color were used to determine fruit ripeness. There are over 30 varieties of apples and 10 varieties of peaches in the orchard and each were monitored separately to help eliminate bias. Nearby orchards were also contacted to find any records of apple and peach ripening dates going back past years.

The climate data came from xmacis (a regional climate database) in Hardin Hall. There is climate data going back to 1887 for Lincoln, NE and many different variations of models were run to interpret the trends of climate over the past 40 years, further back and more recently. The data were retrieved by me from xmacis. Once trends were found I applied them to what would be expected to happen in the future. Models were designed to reflect changes in climate in 30 year overlapping increments from 1893 through 2012. I looked at the minimum temperatures of the months of December, January and February as they primarily have the lowest

temperatures in a given year. This will establish which plants have been able to survive the harshness of winters and which plants are now surviving the winters in Lincoln, Nebraska with current trends.

Second I looked at temperatures in the spring and fall months to determine the lengths of growing season throughout the years and trends of spring minimum and maximum temperatures. I looked at the patterns of the last 40 years, patterns for 30 year overlapping increments and the patterns of the entire climate records going back to 1887. By using the duration of time between when temperatures cross above and drop below freezing, the length of the growing season was determined. The start of the growing season was used to reflect the base as to how many days till a variety of fruit was picked.

For my personal observations in the field the start of the growing season was marked as the base for the two years along with when the fruit were picked. For the following year, the start of the growing season was marked as starting so many days earlier, later or the same as the year before. The same was done with when the fruit was picked.

After all of the data were collected and the graphs were drawn up, I went through and looked for similar trends between the start of the growing season, the minimum temperatures for the winter and the times of when different varieties were picked. Similar trends were noted and with significant evidence, conclusions were made as to which independent factors were influencing fruit ripeness.

This study used a mixed methods approach. I used quantitative and qualitative data for my analysis. The climate data used was entirely quantitative, while the fruit data was quantitative in what I personally found in the two year study and qualitative in what I found from local orchard owners and managers.

## Results

Several aspects of the growing season over the past 40 years were looked at. The first observation is that the start of the growing season has varied. When a trend line was plotted from the years 1975 – 2014, as shown in Figure 2, there is not a significant change in the start of the growing season.

The next observation involves the end of the growing season over the last 40 years. Figure 3 shows that the end of the growing season is trending later, from approximately October 2nd to October 7th. When this trend line is extrapolated another 40 years, it shows the growing season averaging an end 10 days later than 40 years ago.

This shows that the growing season is averaging 5 days longer than 40 years ago and with current trends, the growing season will be another 5 days longer in another 40 years. The average over the 40 year period was 161 days, with the trend line beginning at 158 days, hitting 163 days in 2014 and going to 168 days 40 years in the future. As a note, the growing season in the last 3 years has been below the average of 161 days.

Monthly averages of maximum temperatures for May – August were looked at for the course of the climate record dating back to 1887. When each month was looked at individually, they all trended upward in temperature, as shown in Figure 4. May went from an average of 72 to 75 degrees F. June went from an average of 82 to 85 degrees F. July went from an average of 88.2 to 90 degrees F. August went from an average of 86 to 87.5 degrees F.

The average monthly minimum temperatures for Lincoln, Nebraska from 1887 – 2014 have trended up and down for varying months. January through March have all seen a trend upward (Figure 5), while April through June have both trended downward in minimum temperature averages for the month (Figure 6). Changes in degrees F have occurred as follows: January, -10.5 to -7; February, -7 to -2.5; March, 6 to 8; April, 25.5 to 22; May, 35.5 to 34.5; June 48.5 to 46.5.

Another note, which Figure 7 shows, is that the maximum temperature in February has been increasing from 1887 – present.

The last aspect of climate that I looked at was the overall minimum temperature for a single day record of each winter. The trend from 1888 – 2012 has been a variance of increases and decreases with an overall increase from -15 degrees F to -11 degrees F, shown in Figure 8. The trend over the last 40 years has been from

-19 degrees F to -9.5 degrees F, with a continued trend leading to an overall minimum temperature of 0 degrees F 40 years in the future (Figure 8).

For apple ripening patterns, Figure 9 shows that Midnight Spur, Spartan, Braeburn, Nured Winsap and Chieftain were all later in ripening in 2014 compared to 2013. Orion and Select Spur were both picked earlier and Goldblush did not produce enough apples the second year to be of any significance. Midnight Spur was 4 days later, Spartan was 16 days later, Braeburn was 8 days later, Nured Winsap was 14 days later Chieftan was 3 days later, Select Spur was 21 days earlier and Orion was 19 days earlier.

For pear ripening patterns from 2013 to 2014, Figure 10 shows that Red Sensation and Bartlett both ripened at earlier times. Red Sensation was picked 9 days earlier and Bartlett was picked 18 days earlier.

Elberta Peach and Flamin Fury Peach both did not produce enough peaches to be of significance in 2014. This was because of cold temperatures during bud break and a late frost while the peaches were in bloom, along with hail that knocked many of the remaining developing peaches off.

Figure 11 shows the differences in monthly averaged maximum temperatures between 2013 and 2014 in comparison to the mean, maximums and minimums from 1887 – 2014 (not including November and December for 2014). This shows that February, 2014 was an average of 6.8 degrees F cooler than February, 2013. March 2014 was 5.8 degrees F warmer than March 2013; April, + 7.4; May, + 5.5; June, +2.3, July, 0 degree difference; August, -0.3; September, -6.4. The mean temperature is in between the 2 years for these months, not including July.

The data expressed above were retrieved from the orchard owned by Leon and Helen Page, owners of Page's Countryside Store. Leon is the fruit specialist and he does not have a historical record of bud break, flowering or ripening times. He does have a chart of "Apple Pollination and Average Picking Dates," Figure 12, which he uses as a guide. The rest of his methods are based on years of experience and learning his trees from past patterns. He walks the orchard around the time of bud break to check the health of the year's potential

harvest, checks the condition of the flowers during that time and can then judge an average time of harvest for different varieties.

One condition that is viewed by Windcrest Winery is bud break. Dale Lilyhorn stated that bud break varies from year to year by a couple weeks, but flowering of the grapes is always either June 1st or 2nd. He also said that each variety of grape is picked within 4 to 5 days of the same time each year. When asked if he kept track of the exact day each variety was picked, he said that it varied based on when he could get workers to pick them. He uses a refractometer to measure brick levels when each variety is close to ripening, and then he takes samples to be analyzed for brick and pH levels in the lab when he believes a variety is ready to be picked.

Another orchard that was used in this study was Martin's Hillside orchard. They look at flowering time in the spring of the various apple varieties they have to determine when they will pick their crop later in the summer and fall. They have a standard number of days between flowering time and ripening time for each variety. I was informed that over the years they use the knowledge that the standard number of days is for average temperatures for their region and the ripening can take more or less time based on cooler or warmer temperatures than average. A warmer summer will mean faster ripening and an early harvest, and a cooler summer will mean later harvest relative to flowering time. They did keep track of flowering time, but I was not allowed access to this resource.

## Discussion

The initial Figure 1, from 1973 – 2012, showed a significant change in the start of the growing season, as the trend line starts at approximately April 30th and moves to April 22nd over the 40 year period. The years 2013 and 2014 had the latest starts to the growing season besides the years 1983 and 1997 and were the only consecutive starts later than May 5th in the 40 year record. May 16th in 2014 was the latest start in the 40 year record. The significance of this is that before the last two years there was a significant trend in the start of the growing season being earlier, followed by the 1st and 4th latest starts in the 40 year record.

Fruit ripening of the majority of apple varieties was later in 2014. The mean temperature for the months of January – August in 2014 was warmer than 2013 for every individual month except for in February 2014. The warming in February 2013 caused the apple trees to break dormancy (bud break) earlier than in the following February. This relates directly to the findings of a previous study stating that leaf unfolding and spring flowering are influenced by maximum temperatures (Gordo and Sanz 2005).

There has been a trending increase of February maximum and minimum temperatures. This suggests that these apple trees will tend to break dormancy earlier more often in the future. There has also been a decrease in the minimum temperature in April. The combination of warmer February temperatures and cooler minimum temperatures in April could mean more damaging effects as a large drop in temperature after dormancy is broken would be more likely to happen. Temperatures dropping down after dormancy is broken can damage the buds themselves with temperatures too far below freezing. Flowering trees can be damaged more easily by temperatures at or below freezing. Flowers will freeze and possibly die with a frost or freeze. Once a fruit flower dies it can no longer produce fruit.

There has been an up and down trend with an overall increase in the trend of minimum winter temperature over the last 40 years by more than ¼ of a degree F per year. This allows less hardy plants to be grown in the region theoretically. USDA maps of hardiness zones also show these trends in warmer winters (USDA 2012). The problem comes with winters such as 2014 when temperatures get lower than the recent trend. Minimum temperatures trending upward can give the illusion that the average is the allowable range for plants to be planted, but the buds on trees may not be able to handle the lowest temperatures in the winter for below average years. For example, many of the peach buds for the 2014 crop at Page's Countryside Store were frozen and damaged before they even had the chance to break dormancy in February. The trees still survived, but the crop was damaged significantly for that year. This is one part of why peach trees did not produce well enough in 2014 to compare the two years. The timing of break in dormancy and a late frost, along with several hail storms during flowering caused significant damage to the peach harvest.

There has been a trend upwards in the number of days in the growing season over the last 40 years at a rate of more than one day every 10 years. This allows a longer time that trees have to go from budding out to flowering to fruit ripening. Ideally flowering begins after the last frost in the spring and fruit are ripe and picked before the first frost in the fall.

The data returned from various orchards was more qualitative than quantitative. I found that orchards and the winery I visited tended to keep a general knowledge of developing fruit based on past years and conditions of the trees and vines in the spring.

## Conclusion

The initial bud break towards the end of winter and beginning of spring was the most important factor in setting when the majority of apple varieties would be ready to pick. The temperatures in February have trended upwards indicating a potential earlier trend in the date of bud break in the future. The lengthening in the number of growing season days in a year allows more time for the flowering and ripening patterns of fruit trees, but a decrease in the minimum temperature in April could be trouble for a tree that is trying to flower earlier than usual. When a tree breaks dormancy it begins to move sap around (Leon Page). The moving of nutrients through translocation starts the flowering process, but lower temperatures shortly after have the capability to freeze flowers and/or hinder growth.

When looking towards the future there are several potential implications to look at. There will be a chance of more freezing blooms in the years to come. Precautions should be made to prepare for this occurrence if temperatures start to rise in the winter beyond average levels. Most precautions may involve simply being ready to take a hit in production. Dead buds can be trimmed off to help the overall health of the tree, but this will not necessarily help production for that particular year. A second implication comes from winters not getting as cold as past years on average. Hardiness zones have been pushing north and this has allowed less hardy plants to be planted further north. There still needs to be caution in what is planted and consistent yearly expectations. Many winters may be ideal, but there should still be preparation to take a hit in production during

winters that reach peak low temperatures. There was significant grape vine die back this past year according to Leon Page and there was minimal grape production because of the cold winter.

As the hardiness zones move up, there is potential to grow less hardy plants further north. I did not find significant proof of fruits or vegetables that were being grown in southern Kansas that could not already be grown here. There is however potential for grapes and other fruit trees being grown here to consider production expansion north. This could be significant in increasing total production and bringing production to places that do not have as much competition currently. It could provide an important "foot in the door" as zones move north and production follows.

Some limitations in the study included the inability to find extended records of fruit flowering and/or ripening dates and severe storms wiping out crops of peaches. The orchards all had a general timeline of when different varieties would be ready to pick, but not exact records for previous years. Severe storms with high winds and hail damaged almost the entire 2014 peach crop where data was collected. There was not enough remaining to be of any measurable significance.

Future studies would include a larger study area, more climate variables and more varieties and fruit types. A future study could include orchards spread across states north to south and/or east to west for larger, regional comparisons. More fruit types should be reviewed; including, apples, peaches, pears, apricots, plums, grapes and more. There is a need for more years of concrete data of fruit ripening dates, so a study would need to go for several more years. Climate variables such as precipitation and severe weather are possible inclusions along with the dates of bud break and flowering of trees.

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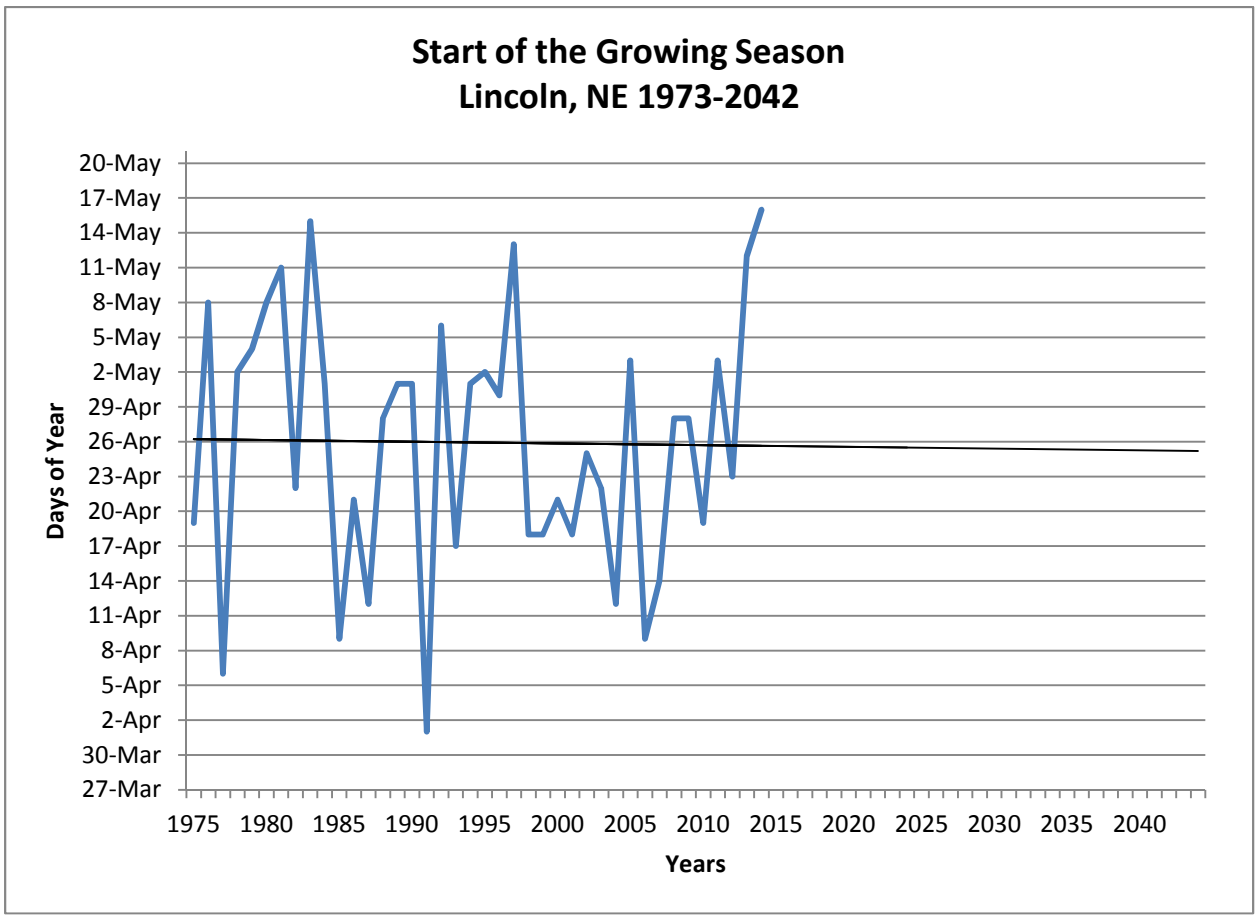
Start of the Growing Season
Lincoln, NE 1973-2042
Days of Year
20-May
17-May
14-May
11-May
8-May
5-May
2-May
29-Apr
26-Apr
23-Apr
20-Apr
17-Apr
14-Apr
11-Apr
8-Apr
5-Apr
2-Apr
30-Mar
27-Mar
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
Years

**Figure 1**

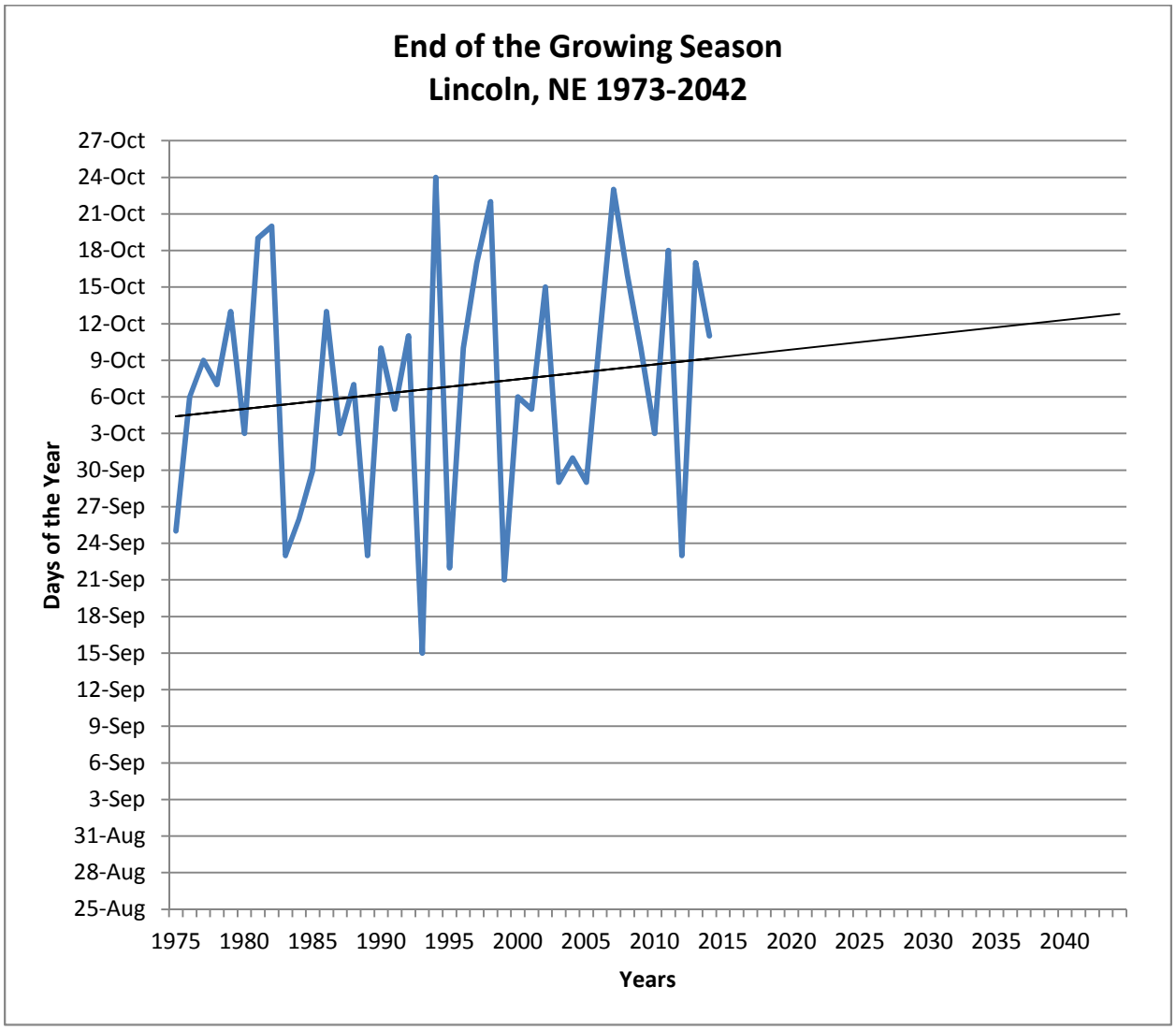
End of the Growing Season
Lincoln, NE 1973-2042
Days of the Year
27-Oct
24-Oct
21-Oct
18-Oct
15-Oct
12-Oct
9-Oct
6-Oct
3-Oct
30-Sep
27-Sep
24-Sep
21-Sep
18-Sep
15-Sep
12-Sep
9-Sep
6-Sep
3-Sep
31-Aug
28-Aug
25-Aug
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
Years

**Figure 2**

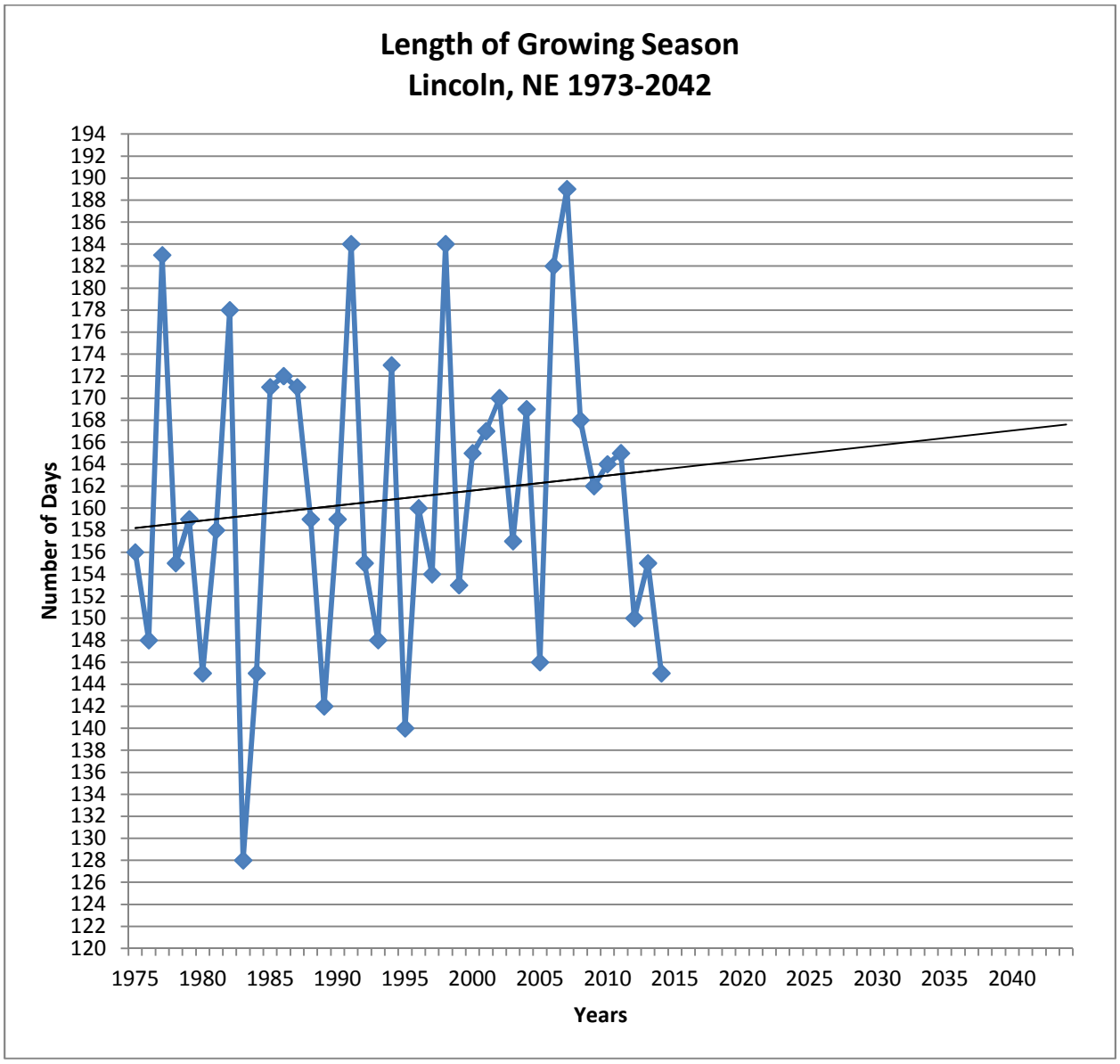
Length of Growing Season
Lincoln, NE 1973-2042
Number of Days
194
192
190
188
186
184
182
180
178
176
174
172
170
168
166
164
162
160
158
156
154
152
150
148
146
144
142
140
138
136
134
132
130
128
126
124
122
120
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
Years

**Figure 3**

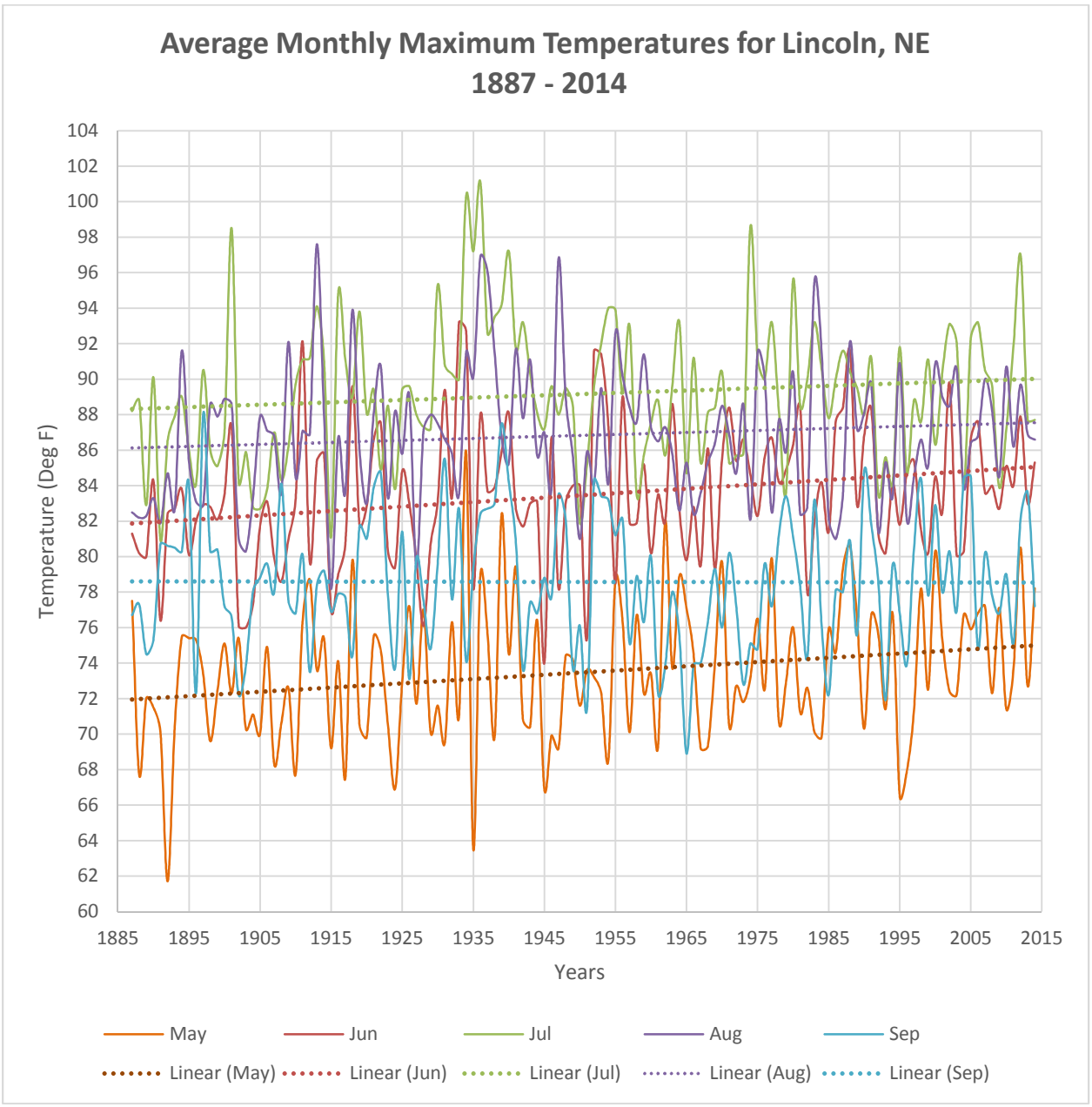
Average Monthly Maximum Temperatures for Lincoln, NE
1887 - 2014
Temperature (Deg F)
104
102
100
98
96
94
92
90
88
86
84
82
80
78
76
74
72
70
68
66
64
62
60
1885
1895
1905
1915
1925
1935
1945
1955
1965
1975
1985
1995
2005
2015
Years
May
Jun
Jul
Aug
Sep
Linear (May)
Linear (Jun)
Linear (Jul)
Linear (Aug)
Linear (Sep)

**Figure 4**

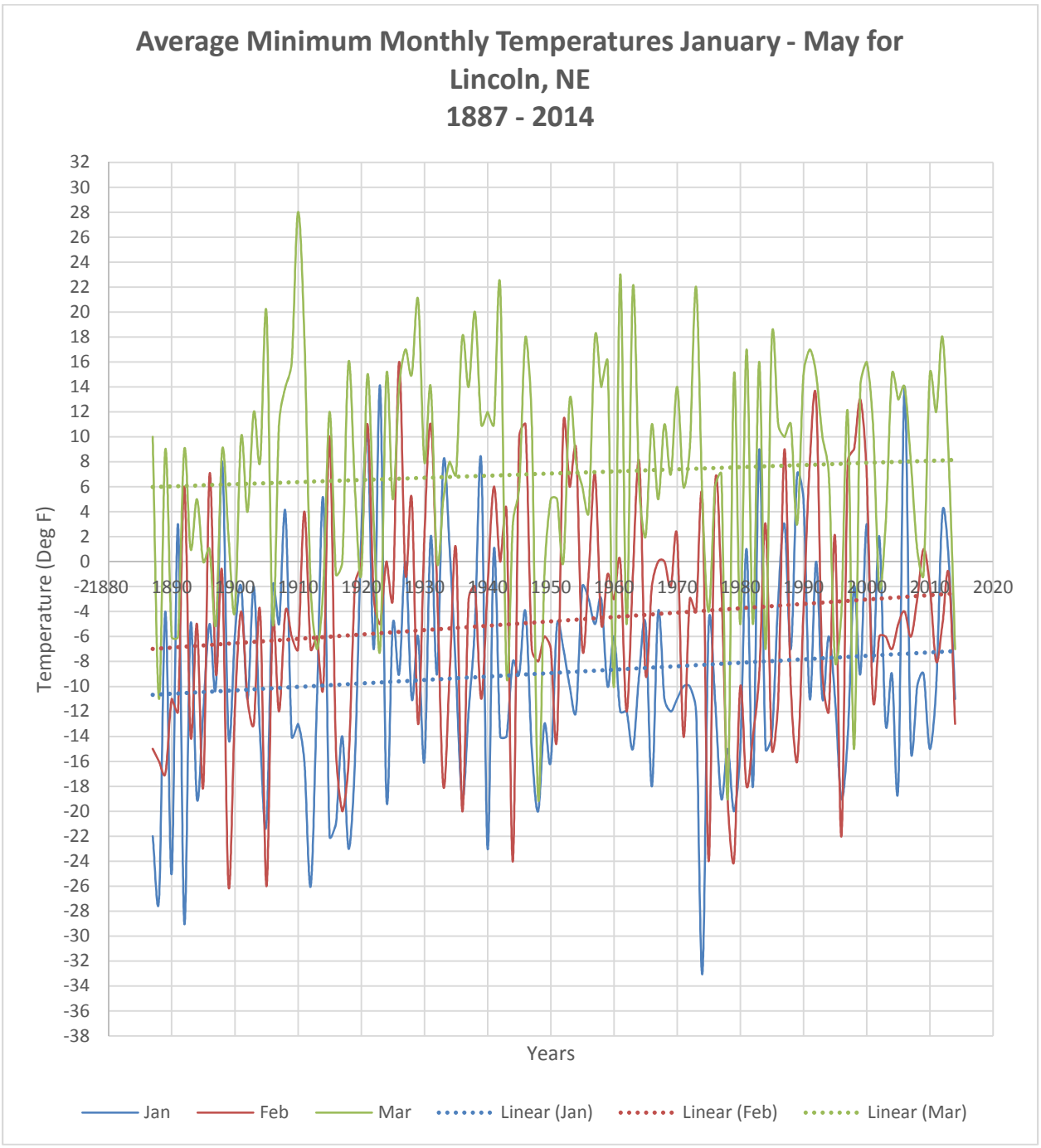
Average Minimum Monthly Temperatures January - May for Lincoln, NE
1887 - 2014
Temperature (Deg F)
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
-32
-34
-36
-38
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Years
Jan
Feb
Mar
Linear (Jan)
Linear (Feb)
Linear (Mar)

**Figure 5**

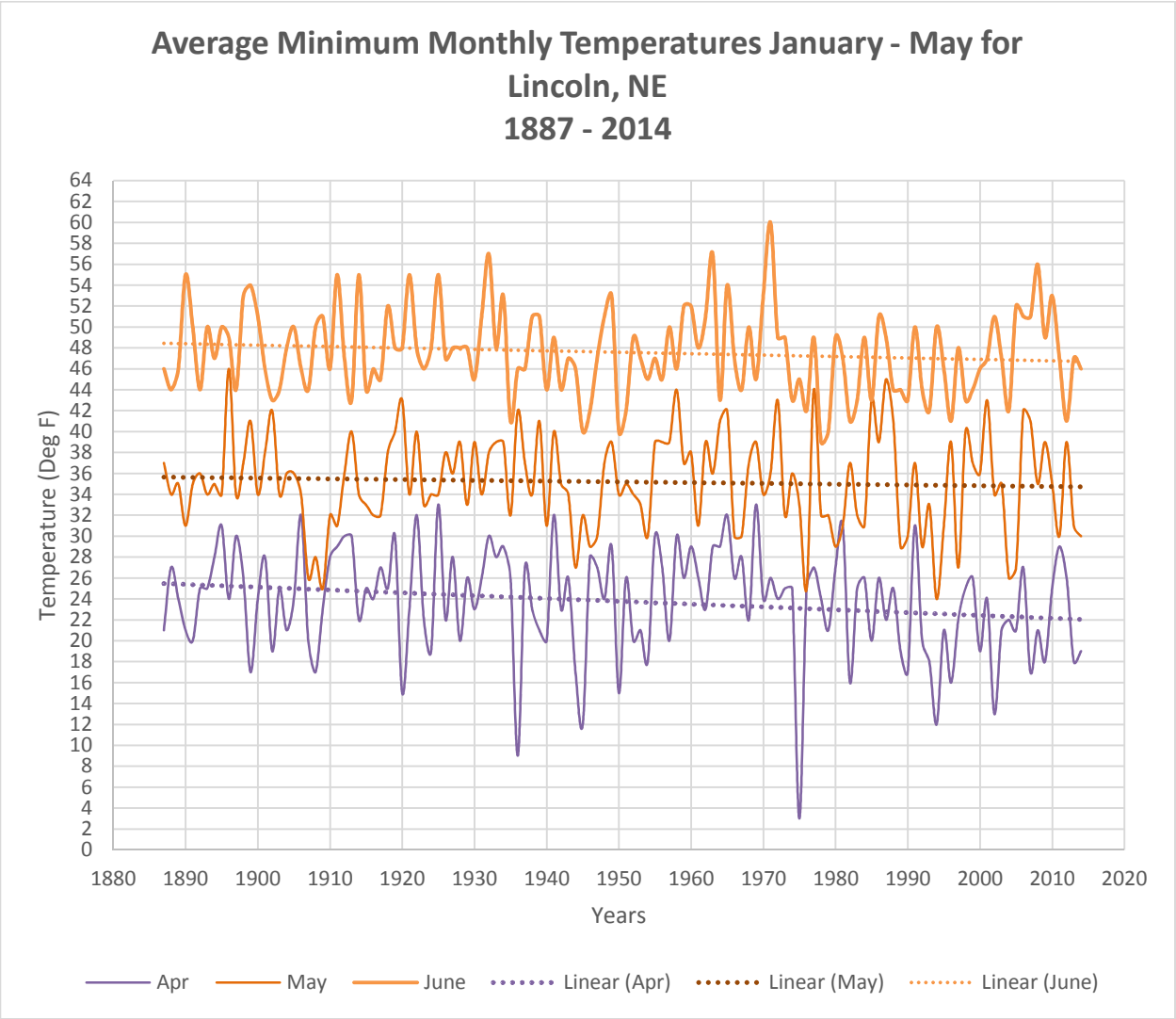
Average Minimum Monthly Temperatures January - May for Lincoln, NE
1887 - 2014
Temperature (Deg F)
64
62
60
58
56
54
52
50
48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Years
Apr
May
June
Linear (Apr)
Linear (May)
Linear (June)

**Figure 6**

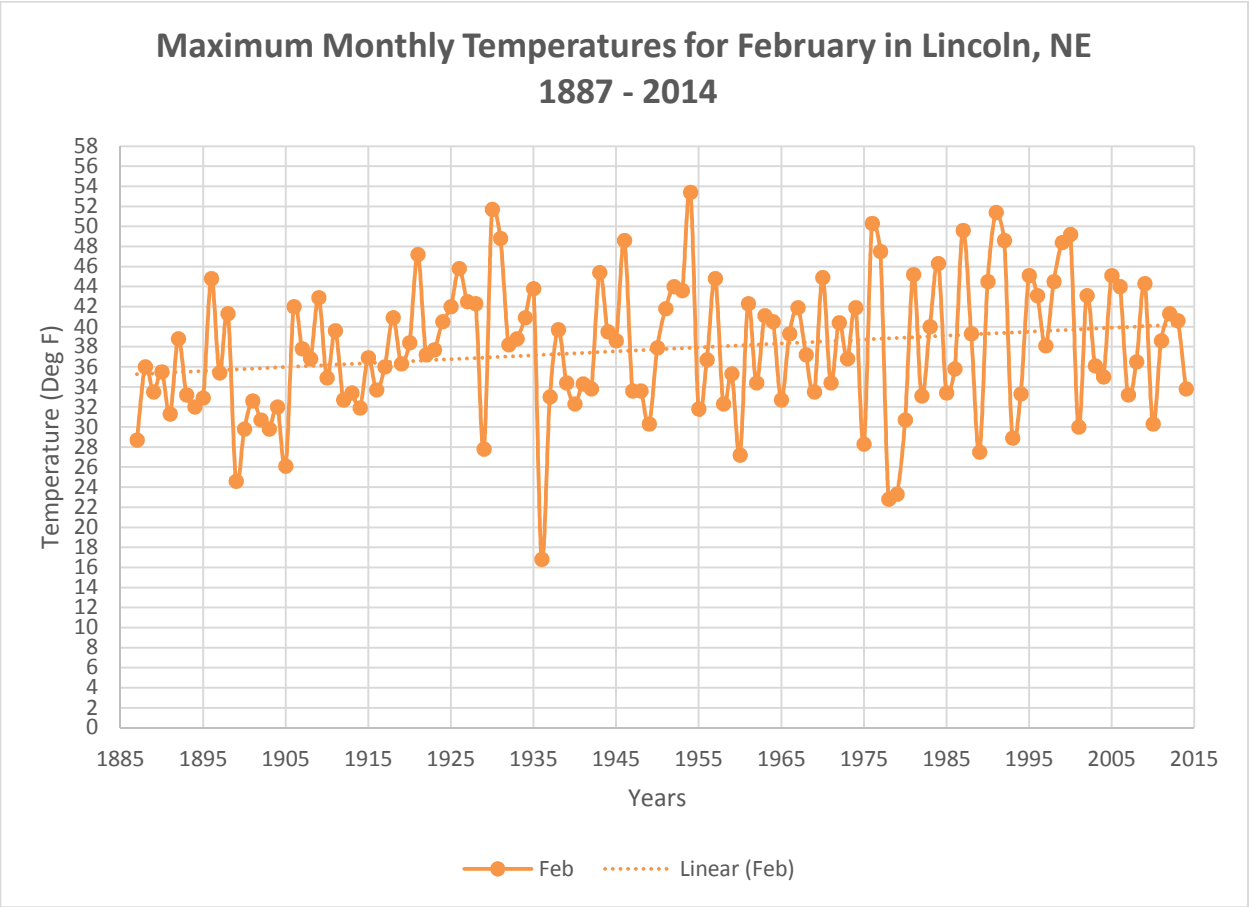
Maximum Monthly Temperatures for February in Lincoln, NE
1887 - 2014
Temperature (Deg F)
58
56
54
52
50
48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
1885
1895
1905
1915
1925
1935
1945
1955
1965
1975
1985
1995
2005
2015
Years
Feb
Linear (Feb)

**Figure 7**

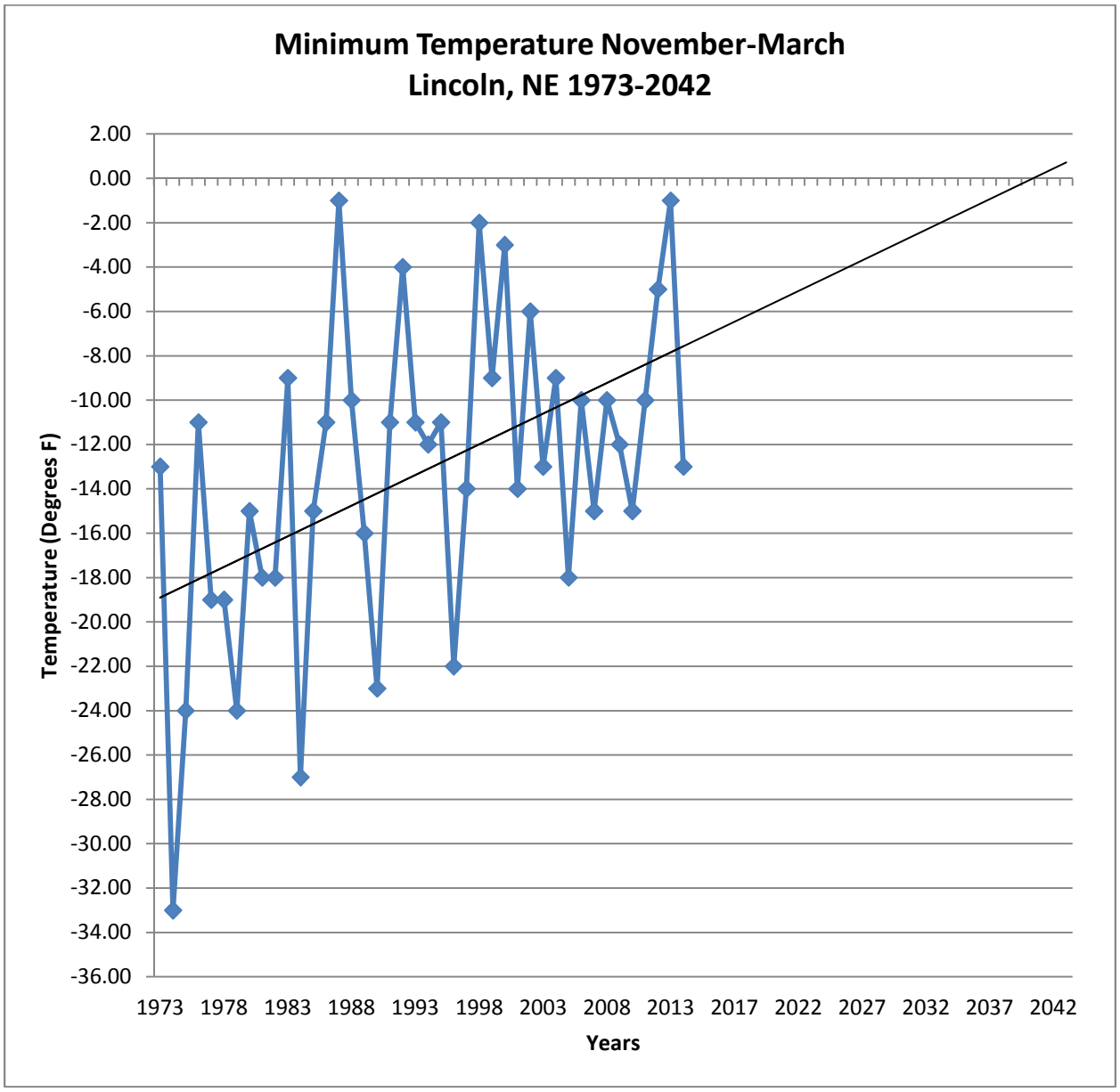
Minimum Temperature November-March
Lincoln, NE 1973-2042
Temperature (Degrees F)
2.00
0.00
-2.00
-4.00
-6.00
-8.00
-10.00
-12.00
-14.00
-16.00
-18.00
-20.00
-22.00
-24.00
-26.00
-28.00
-30.00
-32.00
-34.00
-36.00
1973
1978
1983
1988
1993
1998
2003
2008
2013
2017
2022
2027
2032
2037
2042
Years

**Figure 8**

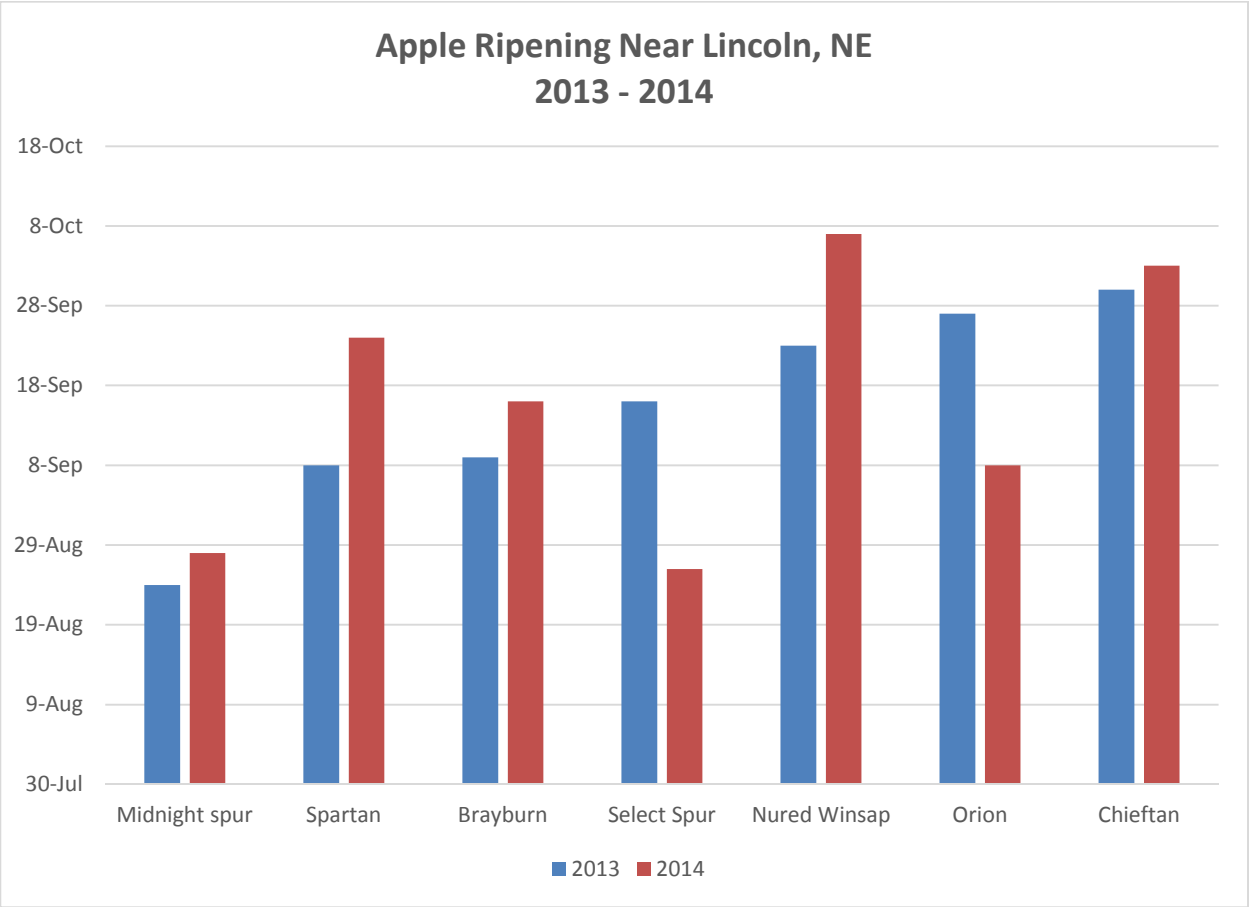
Apple Ripening Near Lincoln, NE
2013 - 2014
18-Oct
8-Oct
28-Sep
18-Sep
8-Sep
29-Aug
19-Aug
9-Aug
30-Jul
Midnight spur
Spartan
Brayburn
Select Spur
Nured Winsap
Orion
Chieftan
2013
2014

**Figure 9**

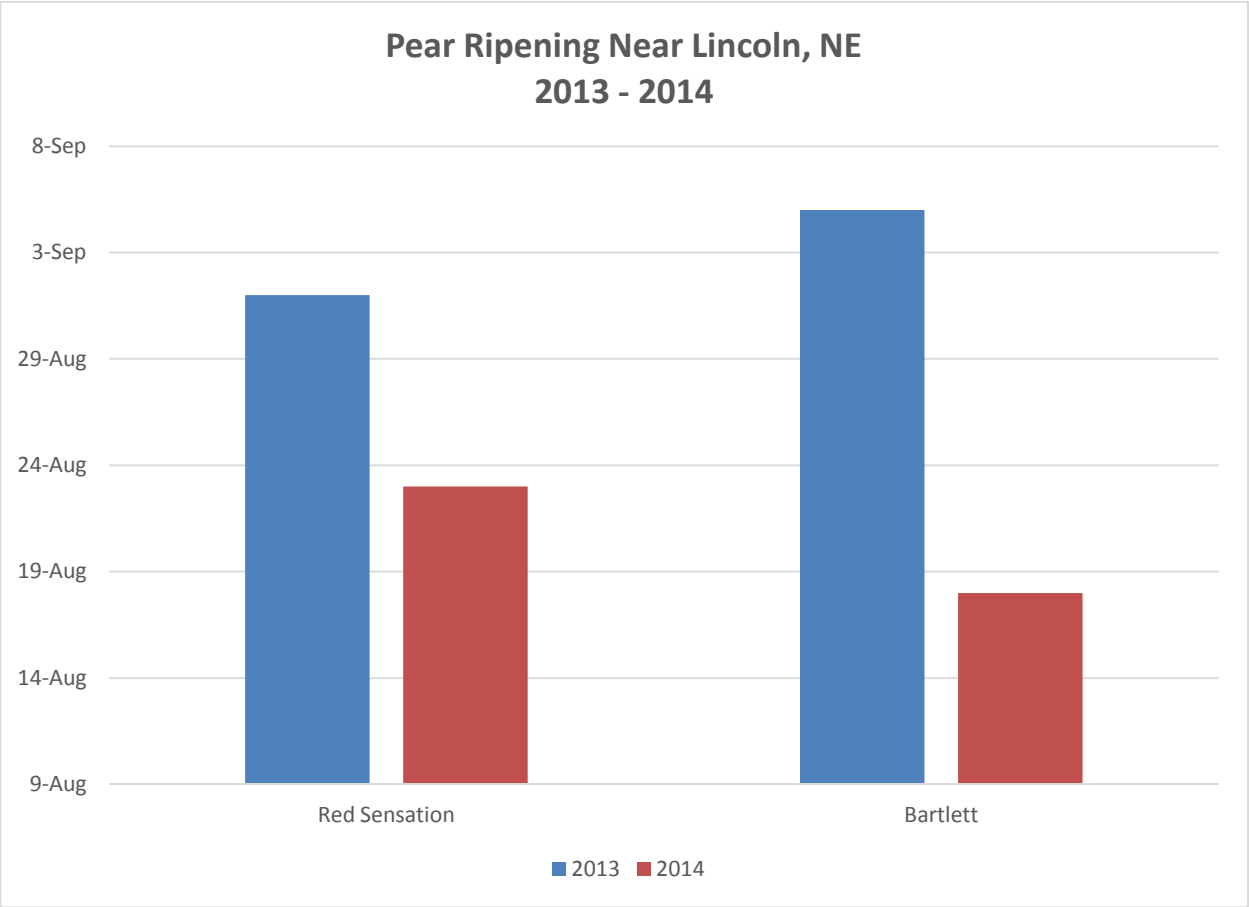
Pear Ripening Near Lincoln, NE
2013 - 2014
8-Sep
3-Sep
29-Aug
24-Aug
19-Aug
14-Aug
9-Aug
Red Sensation
Bartlett
2013
2014

**Figure 10**

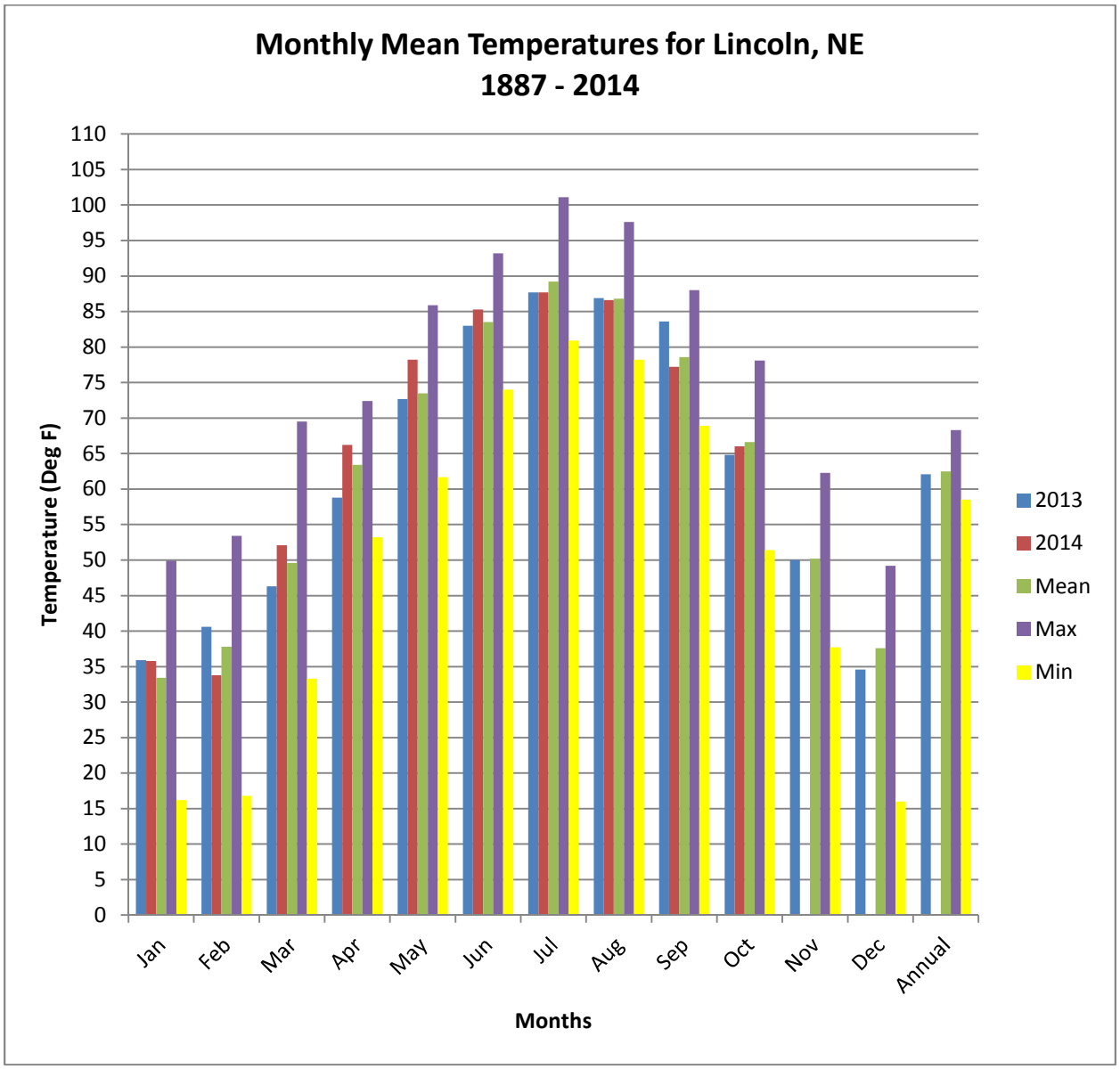
Monthly Mean Temperatures for Lincoln, NE
1887 - 2014
Temperature (Deg F)
110
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Annual
Months
2013
2014
Mean
Max
Min

**Figure 11**

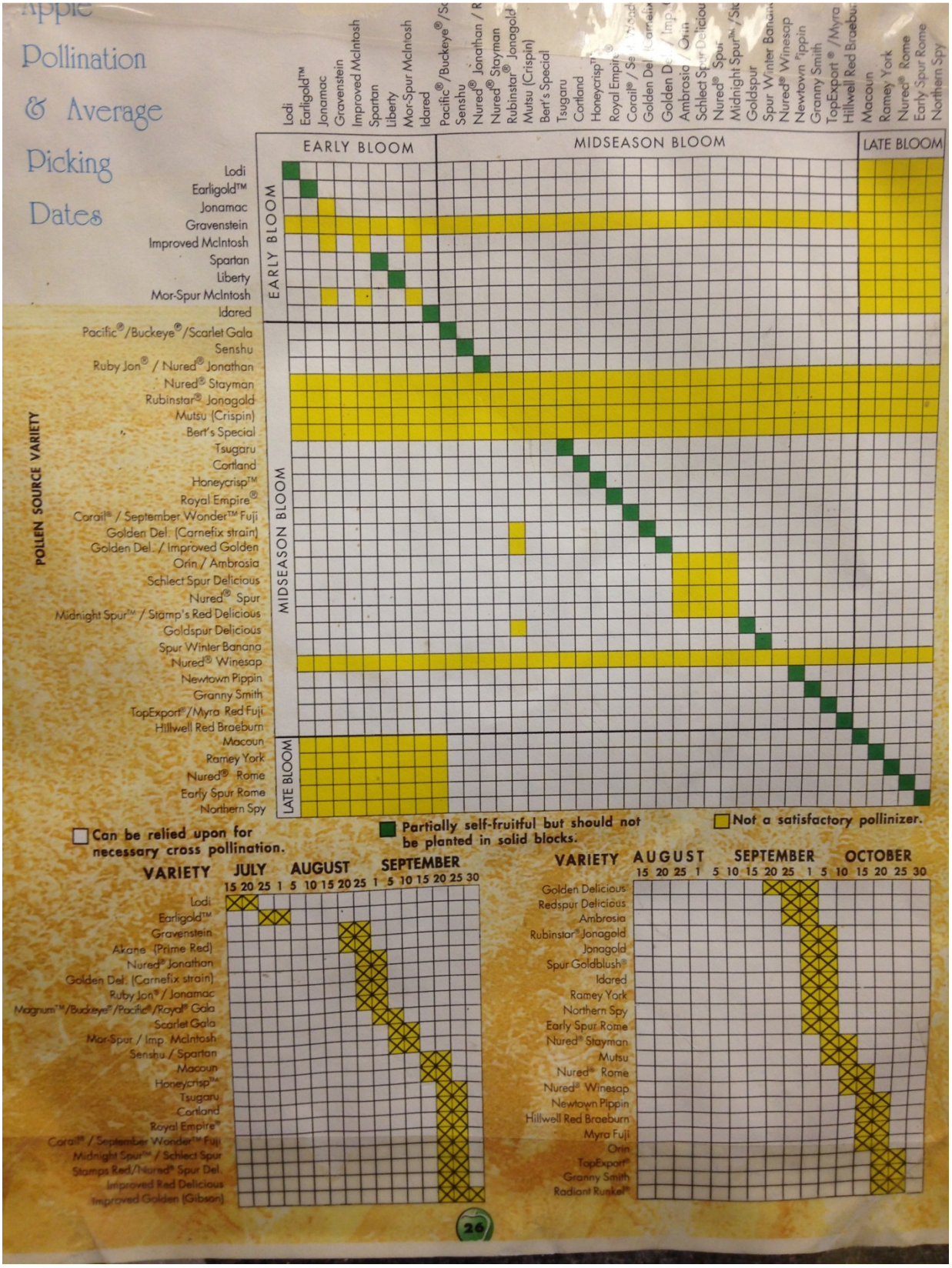


**Figure 12 – Apple pollination and average picking dates obtained from Leon Page**