

Strawberries Production in the US

An Exploratory Data Analysis

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Introduction

Strawberries & Positive Health

Strawberries are a fruit that holds several minerals, vitamins, and nutrients (CRAIG 1997), which have positive implications on human health (Afrin et al. 2016). Specifically, strawberries have been found to help reduce likelihood of cancer, diabetes, obesity, neurodegeneration, cardiovascular disease, and metabolic syndrome (see Figure 1) (Afrin et al. 2016). Although strawberries as a healthy food is the norm, pesticides appear to be harming the beneficial factors of this fruit.

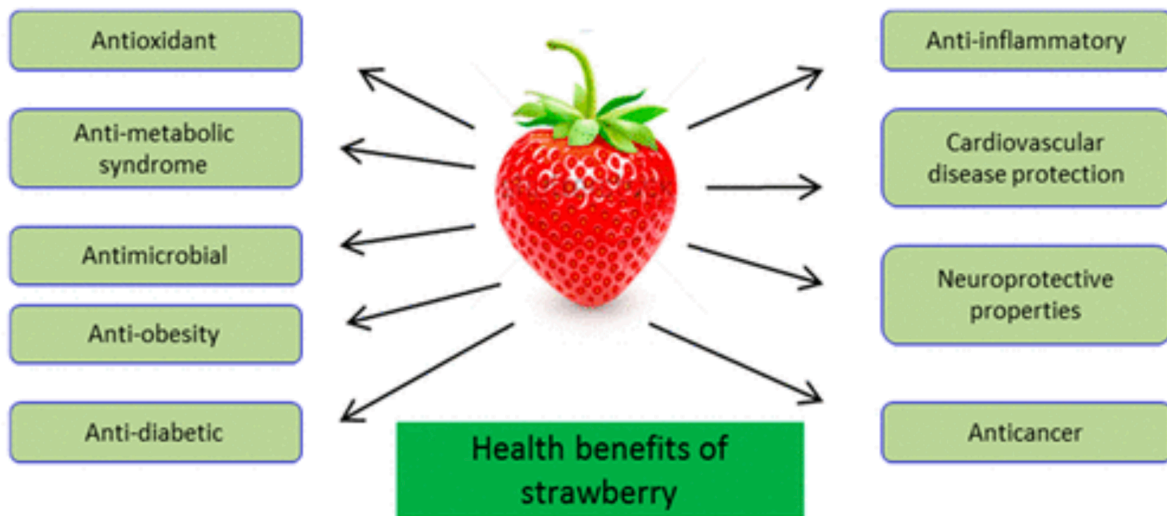


Figure 1: Health benefits of strawberries (Afrin et al., 2016)

Strawberries & Pesticides

Pesticides are used on fruit and vegetable crops, including strawberries, with hopes to increase the quantity (Fenik, Tankiewicz, and Biziuk 2011). Pesticides are made of chemical compounds to reduce or completely eliminate pests from impacting crops (Afrin et al. 2016). These chemical compounds may increase the yield of the crop, but may have a large risk on human health. Additionally, they may contaminate bodies of water and soil with the chemicals, help pests develop resistance to the chemicals, and impact helpful organisms from persisting in areas where pesticides are used. Overall, there are positive and negative impacts of using pesticides (see Figure 2), but it is important to further examine these impacts, specifically on strawberries, to understand the implications of using such.

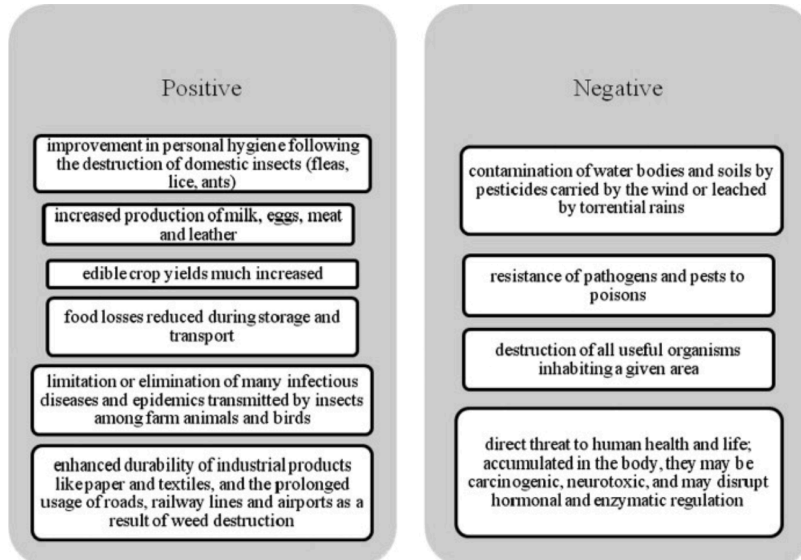
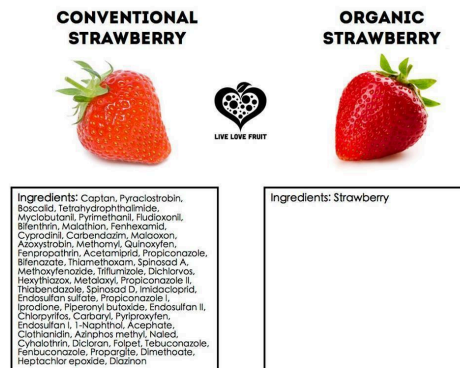


Figure 2: Positive and negative implications of pesticides on fruit and vegetable crops (Fenik et al., 2011)

Organic Strawberries

Strawberries that are organic are simply strawberries. They use alternative and safer methods to production, and those fruits and vegetables, in this case strawberries, are considered organic (Verteramo Chiu and Gomez 2023). Along with these alternative methods comes a higher cost of production and care, which increases the price to the consumer.



Analyzing Strawberry Production

The literature varies on if organic or non-organic is environmentally better (Afrin et al. 2016). This exploratory data analysis on production of strawberries, which encompasses both pro-

cessed (non-organic) and fresh (organic) market data, will help us better understand production of strawberries in the United States. Additionally, it dives deeper into the pesticide usage in states, which will provide more information as to the level of toxic ingredients that go into the production of non-organic (or conventional) strawberries .

Data Acquisition & Assessment

USDA-NASS Data

The data was acquired from [U.S. Department of Agriculture \(USDA\)](#) and the [National Agricultural Statistics Service \(NASS\)](#). The data was uploaded for data cleaning and organizing and exploratory data analysis by Professor Haviland Wright, who chose the following data: [USDA-NASS](#).

The data frame loaded into the environment is titled `strawberry`.

Rows: 4,314

Columns: 21

```
$ Program      <chr> "CENSUS", "CENSUS", "CENSUS", "CENSUS", "CENSUS", "~
$ Year         <dbl> 2021, 2021, 2021, 2021, 2021, 2021, 2021, 2021, 202~
$ Period       <chr> "YEAR", "YEAR", "YEAR", "YEAR", "YEAR", "YEAR", "YE~
$ `Week Ending` <lgl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA,~
$ `Geo Level`  <chr> "STATE", "STATE", "STATE", "STATE", "STATE", "STATE~
$ State        <chr> "ALASKA", "ALASKA", "ALASKA", "ALASKA", "ALASKA", "~
$ `State ANSI` <chr> "02", "02", "02", "02", "02", "02", "02", "06", "06~
$ `Ag District` <lgl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA,~
$ `Ag District Code` <lgl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA,~
$ County       <lgl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA,~
$ `County ANSI` <lgl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA,~
$ `Zip Code`   <lgl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA,~
$ Region       <lgl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA,~
$ watershed_code <chr> "00000000", "00000000", "00000000", "00000000", "00~
$ Watershed    <lgl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA,~
$ Commodity    <chr> "STRAWBERRIES", "STRAWBERRIES", "STRAWBERRIES", "ST~
$ `Data Item`  <chr> "STRAWBERRIES, ORGANIC - OPERATIONS WITH SALES", "S~
$ Domain       <chr> "ORGANIC STATUS", "ORGANIC STATUS", "ORGANIC STATUS~
$ `Domain Category` <chr> "ORGANIC STATUS: (NOP USDA CERTIFIED)", "ORGANIC ST~
$ Value        <chr> "2", "(D)", "(D)", "(D)", "2", "(D)", "(D)", "142",~
$ `CV (%)`     <chr> "(H)", "(D)", "(D)", "(D)", "(H)", "(D)", "(D)", "1~
```

Census Data

The data offers census data based on state that represents fresh market (organic) and process market (non-organic) sales.

Rows: 864

Columns: 21

```

$ Program          <chr> "CENSUS", "CENSUS", "CENSUS", "CENSUS", "CENSUS", "~
$ Year             <dbl> 2021, 2021, 2021, 2021, 2021, 2021, 2021, 2021, 202~
$ Period           <chr> "YEAR", "YEAR", "YEAR", "YEAR", "YEAR", "YEAR", "YE~
$ `Week Ending`   <lgl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, ~
$ `Geo Level`     <chr> "STATE", "STATE", "STATE", "STATE", "STATE", "STATE~
$ State            <chr> "ALASKA", "ALASKA", "ALASKA", "ALASKA", "ALASKA", "~
$ `State ANSI`    <chr> "02", "02", "02", "02", "02", "02", "02", "06", "06~
$ `Ag District`   <lgl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, ~
$ `Ag District Code` <lgl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, ~
$ County           <lgl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, ~
$ `County ANSI`   <lgl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, ~
$ `Zip Code`      <lgl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, ~
$ Region           <lgl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, ~
$ watershed_code   <chr> "00000000", "00000000", "00000000", "00000000", "00~
$ Watershed        <lgl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, ~
$ Commodity        <chr> "STRAWBERRIES", "STRAWBERRIES", "STRAWBERRIES", "ST~
$ `Data Item`     <chr> "STRAWBERRIES, ORGANIC - OPERATIONS WITH SALES", "S~
$ Domain           <chr> "ORGANIC STATUS", "ORGANIC STATUS", "ORGANIC STATUS~
$ `Domain Category` <chr> "ORGANIC STATUS: (NOP USDA CERTIFIED)", "ORGANIC ST~
$ Value            <chr> "2", "(D)", "(D)", "(D)", "2", "(D)", "(D)", "142",~
$ `CV (%)`        <chr> "(H)", "(D)", "(D)", "(D)", "(H)", "(D)", "(D)", "1~

```

Survey Data

Additionally, it holds survey information for each state, specifically indicating pesticides and bacterium used to preserve strawberry crop yield. In addition, it offers fresh and process market data.

Rows: 3,450

Columns: 21

```

$ Program          <chr> "SURVEY", "SURVEY", "SURVEY", "SURVEY", "SURVEY", "~
$ Year             <dbl> 2022, 2022, 2022, 2022, 2022, 2022, 2022, 2022, 202~
$ Period           <chr> "MARKETING YEAR", "MARKETING YEAR", "MARKETING YEAR~
$ `Week Ending`   <lgl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, ~
$ `Geo Level`     <chr> "STATE", "STATE", "STATE", "STATE", "STATE", "STATE~
$ State            <chr> "CALIFORNIA", "CALIFORNIA", "CALIFORNIA", "FLORIDA"~
$ `State ANSI`    <chr> "06", "06", "06", "12", "12", "12", NA, NA, NA, "06~
$ `Ag District`   <lgl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, ~
$ `Ag District Code` <lgl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, ~
$ County           <lgl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, ~
$ `County ANSI`   <lgl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, ~

```

```

$ `Zip Code`      <lgl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA,~
$ Region          <lgl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA,~
$ watershed_code  <chr> "00000000", "00000000", "00000000", "00000000", "00~
$ Watershed       <lgl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA,~
$ Commodity       <chr> "STRAWBERRIES", "STRAWBERRIES", "STRAWBERRIES", "ST~
$ `Data Item`     <chr> "STRAWBERRIES - PRICE RECEIVED, MEASURED IN $ / CWT~
$ Domain          <chr> "TOTAL", "TOTAL", "TOTAL", "TOTAL", "TOTAL", "TOTAL~
$ `Domain Category` <chr> "NOT SPECIFIED", "NOT SPECIFIED", "NOT SPECIFIED", ~
$ Value           <chr> "108", "(D)", "(D)", "169", "(D)", "(D)", "0", "135~
$ `CV (%)`        <chr> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA,~

```

States

There were 47 states (c("ALASKA", "CALIFORNIA", "CONNECTICUT", "FLORIDA", "GEORGIA", "IDAHO", "ILLINOIS", "INDIANA", "IOWA", "KENTUCKY", "LOUISIANA", "MAINE", "MARYLAND", "MASSACHUSETTS", "MICHIGAN", "MINNESOTA", "MONTANA", "NEBRASKA", "NEW HAMPSHIRE", "NEW JERSEY", "NEW YORK", "NORTH CAROLINA", "OHIO", "OKLAHOMA", "OREGON", "PENNSYLVANIA", "RHODE ISLAND", "SOUTH CAROLINA", "SOUTH DAKOTA", "TENNESSEE", "VERMONT", "WASHINGTON", "WEST VIRGINIA", "WISCONSIN", "ALABAMA", "ARIZONA", "COLORADO", "KANSAS", "MISSOURI", "NEVADA", "NEW MEXICO", "VIRGINIA", "ARKANSAS", "NORTH DAKOTA", "TEXAS", "UTAH", "OTHER STATES")) with two states considered as "other states".

Years

The data was from the years c(2021, 2019, 2016, 2022, 2020, 2018, 2017).

Assumptions & Motivations

Census Data

The `census` data was a nation-wide collection of data about the fresh and process markets related to strawberries. This data has values that are indicated as (D), which are data that was withheld upon request by the strawberry market in that particular state. This could leave out important information in the data.

Survey Data

The survey data was collected via a survey sent out to each state in the United States. There were only 11 out of 47 states who returned the survey (c("CALIFORNIA", "FLORIDA", "OTHER STATES", "NEW YORK", "NORTH CAROLINA", "OREGON", "WASHINGTON", "MICHIGAN", "OHIO", "PENNSYLVANIA", "WISCONSIN")), which includes the "other states". (The "other states" did not have any data relating to pesticides and bacterium.) This is only a 23% response rate, which is not comprehensive of all the states and the entire United States process market. The states that did return the survey will still be able to show a report of pesticide and bacterium usage on their processed strawberry crops.

Data Cleaning & Organizing

R Packages

The following R packages were used to clean and organize the data:

```
library(knitr)
library(kableExtra)
library(tidyverse)
library(stringr)
library(dplyr)
```

The data was organized into two main categories: **census** and **survey**. The **census** data was cleaned and organized to show fresh and process market sales, and the **survey** data consisted of pesticide and fertilizer usage.

Initial Data Cleaning & Organization

The following initial data cleaning derived from Professor Wright.

Removed columns with a single value in all columns using a function. This function produced all columns with one value from the **strawberry** data frame. From there, all but the single value columns were added back to the data frame.

Next, Professor Wright checked if every row in the **state** column held a value, which it did.

After that, Professor Wright checked to see what state had the most rows.

The state with the most rows is CALIFORNIA.

Separating Data Frames

The following separation of data frames derived from Professor Wright.

By using **dplyr**, the **strawberry** data frame was split by **Program**. The rows that contained **CENSUS** were moved to **strwb_census**, and the rows containing **SURVEY** were moved to **strwb_survey**.

Census

After splitting `CENSUS` and `SURVEY` rows into two data frames, Professor Wright has first organized the `CENSUS` data.

First, he separated composite columns and cleaned the `Value` column.

The composite columns in the `strwb_census` are as follows: `Data Item` and `Domain category`.

The column separators in `CENSUS` are “,”, “-”, “:”.

Separated `Data Item` into the new columns `Fruit`, `temp1`, `temp2`, and `temp3` by “,”.

Separated `temp1` into the new columns `crop_type` and `prop_acct` by “-”.

To finish this first section of cleaning and organizing the `strwb_census` data frame, Professor Wright string trimmed both sides of the following three columns: `crop_type`, `temp2`, and `temp3`.

Now, Professor Haviland created a “Fresh Market” column. To do this, he duplicated the `temp2` column with the new column name as `Fresh Market`. Next, he removed all the cells in the new column that began with `MEASURED`. Same for the cells that begin with `PROCESSING`. He substituted `NA` values for empty strings. Finally, the `FRESH MARKET` parts of the strings were removed, as they were unnecessary anymore with the new column creation of `Fresh Market`.

Now, to manipulate the `temp2` column, Professor Wright removed all the cells that began with `FRESH`, which would now set up the cleaning and organizing to create the `Process Market` column.

Professor Wright created a “Process Market” column.

To do this, he followed the same method as `Fresh Market`, where he first duplicated `temp2`, then removed cells beginning with `MEASURED`, and removed `PROCESSING` from the beginning of the strings. and remove

Finally, removed the cells starting with `PROCESS MARKET` from `temp2`.

Next, Professor Wright removed `NA`’s from `prop_acct`, `temp2`, and `temp3` by substituting a space.

From here, he combined `temp2` with `temp3` to create a `Metric` column. He also removed parts of string that did not matter, beginning with `MEASURED IN`. To finish, he moved the `Metric` column to the end.

The `Value` column was transformed. To do this, Professor Wright first pulled the `Value` column from `strwb_census` and put them into `vals`. From there, he string replaced all `vals` to remove

the commas in the strings. From there, he converted the strings to numeric values. During this, NA values were automatically implemented.

After this, he aimed to find the location and value of the footnotes in the **Value** column. He implemented a string detection on this column, which helped discover that all the cells with NA values were also where the footnotes were located. The footnotes indicated that the **Value** was instructed to be left out during the data collection.

I finished cleaning and organizing the **strwb_census** data frame, which is detailed below.

First, I selected particular columns that had necessary data.

Next, I removed the “,” from the **Value** column and transformed them into numeric values. This introduced rows with NA values.

After that, I cleaned up the **CV (%)** column by changing the values to numbers, instead of strings. This also introduced rows with NA values.

Furthermore, I am going to omit all rows in the **Value** and **CV (%)** columns with NA values. These are being omitted because they hold no meaning. Only the **Value** column had to be adjusted, as the **CV (%)** column did not have any values if the **Value** column also did not.

Finally, to complete the **strwb_census** cleaning and organizing, I am going to arrange the **State** column to be in ascending order.

Survey

Professor Wright had organized the **SURVEY** data frame splitting the marketing, and production data from the chemical application data. In the strawberry data frame, The **CENSUS** rows contain marketing, sales, and production data. The **SURVEY** rows contain rows which may be redundant with the **CENSUS** rows and chemical application rows. These rows contain fresh and process market sales data, which have been removed.

Began cleaning and organizing **strwb_survey** by discovering what columns in this data frame that need to be split.

First, Professor Wright separated the **Data Item** column to **temp1**, **temp2**, **temp3**, and **temp4** by “,”. Additionally, he separated **temp1** into **temp1a** and **temp1b**.

Next, he separated the **Domain** column into **temp22** and **temp23** by “,”.

Also, he separated **Domain Category** into **temp42** and **temp43** by “,”.

To finish the **strwb_survey** cleaning and organizing, this data frame was split into two new data frames, where **strwb_survey_chem** holds pesticide data and **strwb_survey_mkt** contains all the surveyed market and fertilizer usage data.

Survey: Market

Now, I further cleaned up both `strwb_survey_mkt` and `strwb_survey_chem`. First, I worked with the `strwb_survey_mkt`.

Quickly, to begin, Professor Wright Dropped one-value columns in `strwb_survey_mkt`.

To begin, I made the `Value` column into numeric values, which introduced NA values. Then, I changed the format of the numeric values, so they did not appear in scientific notation.

To reduce the duplicity of `strwb_survey_mkt` with `strwb_census`, I separated the fresh and process market data in `strwb_survey_mkt` from the data on the fertilizer usage.

Next, I separated the `temp42` column to create the columns `type` and `fertilizer_type` by the delimiter “.”.

I cleaned up the `fertilizer_type` strings by removing the parentheses on both sides.

I also removed the empty spaces in these strings.

Finally, I selected the rows that are relevant and renamed `temp3` to `measurement` and `temp4` to `avg`. I also removed the empty spaces in these strings and made the `Value` column into numeric values, which introduced NA values, and those rows with NA values were omitted.

Survey: Chemical

Finally, I finished cleaning and organizing `strwb_survey_chem`.

First, Professor Haviland dropped one-value columns in `strwb_survey_chem`.

Then, I selected the relevant columns.

From here, I split up `temp43` into `chemical` and `PC#` by “=”.

Furthermore, I cleaned up both of the new `chemical` and the `PC#` columns by removing the unnecessary parentheses.

I also want to separate the `chemical` column by chemical type and chemical name.

Trimmed off the spaces on both sides of the `chemical` column.

Trimmed the same to `chem_type`.

Finally, trimmed the same with `PC#`.

Now to remove the rows with NA values in the `PC#` column.

Addition to Strwb_Survey_Chem: WHO Chemical Toxicity

Now, to better understand the `strwb_survey_chem` data, I added two columns of data. We are first going to begin with “chemical toxicity” (`toxicity`).

To gather this information, I used the World Health Organization (WHO)’s classification of pesticides by hazard [WHO, 2019]. Table 1 shows the WHO’s toxicity classification for pesticides.

Class	Description	LD ₅₀ for the Rat (mg/kg Body Weight)			
		Oral		Dermal	
		Solids	Liquids	Solids	Liquids
Ia	Extremely hazardous	≤5	≤20	≤10	≤40
Ib	Highly hazardous	5–50	20–200	10–100	40–400
II	Moderately hazardous	50–500	200–2,000	100–1,000	400–4,000
III	Slightly hazardous	>500	>2,000	>1,000	>4,000

doi:10.1371/journal.pmed.1000357.t001

Figure 3: Table 1. World Health Organization Pesticide Toxicity Classification

Additionally, some chemicals are presented as fatal or toxic if inhaled, as they are gaseous or volatile fumigants [WHO, 2019]. Others are classified as “unlikely to present acute hazard” by WHO [WHO, 2019], which means that they will not present any hazard if used properly. Furthermore, they are also classified as “no significant acute toxicity” when they are not in the WHO classification and are found to be non-toxic, mostly discovered through the Environmental Protection Agency (EPA) [EPA].

I classified each chemical toxicity by the string `Highly hazardous`, `Moderately hazardous`, `Unlikely to present acute hazard`, `Slightly hazardous`, `Fatal if inhaled`, `Toxic if inhaled`, `No significant acute toxicity` and `Not specified`, based on the WHO chemical toxicity rating system [WHO, 2019].

I searched through each classification table to find each pesticide. Not all pesticides were on the table. To find the missing chemical toxicities, I used the large language model, Chat GPT [Chat GPT], found information through EPA Pesticide Fact Sheets [EPA-Acibenzolar], [EPA-Ammonium], [EPA-Aureobasidium], [EPA-Canola], [EPA-Caprylic], [EPA-Capasaicin], [EPA-Clethodim], [EPA-Cyflufenamid], [EPA-Cytokinin],

[EPA-Indole.], [EPA-Iron-Phos.], [EPA-Mefenoxam], [EPA-Metam-sodium], [EPA-Polyoxin], [EPA-Potassium], [EPA-Potassium-salts], [EPA-Potassium-silicate], [EPA-Spiromedifen], [EPA-STREPTOMYCES-LYDICUS], [EPA-SULFENTRAZONE], [EPA-SULFUR], and in other sources (Kilani-Morakchi, Morakchi-Goudjil, and Sifi 2021), [PubChem-Capric], [Carfentrazone-ethyl], [Pub-Chem-Copper.], [Copper-Octanoate], [ACS-Copper-Oxide], [Cyprodinil], [DECYLDIMETHYLOCTYL], [Didecyl.], [Dodine], [Sodium-Ferric-Ethyl.], [Garlic-Oil], [Glyphosate], [Hydrogen-Peroxide], [Isofetamind], [Methoxyfenozide], [Mineral-oil], [Mono-Potassium-Salt], [Mustard-oil], [Peroxyacetic-acid], [Quinoline], [CDC-PYRACLOSTROBIN], [SOYBEAN-OIL].

Furthermore, through this search, I discovered through Chat GPT [Chat GPT], that many of the “chemicals” were actually bacterium. I found the toxicity of the bacterium via web search from various sources [BACILLUS AMYLOLIQUEFAC F727.], [BACILLUS AMYLOLIQUEFACIENS MBI 600], [BACILLUS AMYLOLIQUEFACIENS STRAIN D747], [BACILLUS PUMILUS], [BACILLUS SUBTILIS], [ALKYL. DIM. BENZ. AM], [AUREOBASIDIUM PULLULANS DSM 14940], [BACILLUS SUBT. GB03], [BEAUVERIA BASSIANA], [BLAD], [BT KURSTAK ABTS-1857], [BT], [BURKHOLDERIA A396 CELLS & MEDIA], [CAPSICUM OLEORESIN EXTRACT], [CHROMOBAC SUBTUGAE PRAA4-1 CELLS AND SPENT MEDIA], [GLIOCLADIUM VIRENS], [HARPIN A B PROTEIN], [HELICOVERPA ZEA NPV], [NEEM OIL], [PAECILOMYCES FUMOSOR], [PETROLEUM DISTILLATE], [PSEUDOMONAS CHLORORAPHIS STRAIN AFS009], [REYNOUtria SACHALINE], [TRICHODERMA HARZ.], [TRICHODERMA VIRENS STRAIN G-41].

There were three Unknown values for COPPER ETHANOLAMINE, KANTOR, and HALOSULFURON-METHYL, which did not have any clear information on toxicity.

Addition to Strwb_Survey_Chem: CAS Registry Number

Now, the second added column represents each pesticide’s Chemical Abstract Service (CAS) Registry Number (CAS#). A CAS Registry Number allows each chemical compound, including molecular formulas, chemical structures, generic, systematic, common, and trade names, to have a clear identification number [CAS].

To find the CAS#s of each pesticide, I used [WHO, 2019], [CHAT GPT], and, mainly, the United States Environmental Protection Agency’s Pesticide Chemical Search [EPA-search]. After discovering that some of the rows in `chemical` are actually bacterium, all values that do not have CAS#s are indicated as `Bacteria`. All the other chemicals were matched with their appropriate CAS#.

Quickly, I reorganized `strwb_survey_chem` to have the columns in a different order.

I also changed the column name from `chemical` to `strwb_treatment`, as bacterium are not chemicals.

Finally, to finish the data cleaning and organization of `strwb_survey_chem`, I changed the name of the data frame to `strwb_survey_treat` (`treat = treatment`) to avoid confusion, since it is known that all strawberry pesticide treatments are not only chemicals but also bacterium.

Exploratory Data Analysis

Now, to begin the Exploratory Data Analysis of the [USDA-NASS](#) data set. First, I have reviewed each data frame associated with the data set. Next, I searched for and examined any missing values in the data frames. After that, I categorized the values in the data set to prepare for visualization. Finally, I analyzed the relationships in the data frames through visualization and located any outliers [[EDA-Advice](#)].

Review of Data Frames

`strwb_census`

Columns & Values

The column names in `strwb_census` are as follows: `Program`, `Year`, `State`, `Fruit`, `crop_type`, `Totals`, `Fresh Market`, `Process Market`, `Metric`, `Value`, and `CV (%)`.

`Program`

`Program` has a single string of `CENSUS` in every column. `CENSUS` represents that the data derived from a census of states based on their strawberry production.

`Year`

`Year` represents the years in which the data was collected. The years are as follows: `c(2019, 2021, 2016)`.

`State`

`State` holds all the US states that held any census data on their strawberry production (`c("ALABAMA", "CALIFORNIA", "COLORADO", "CONNECTICUT", "FLORIDA", "GEORGIA", "IDAHO", "ILLINOIS", "IOWA", "KANSAS", "KENTUCKY", "LOUISIANA", "MAINE", "MARYLAND", "MASSACHUSETTS", "MICHIGAN", "MONTANA", "NEW HAMPSHIRE", "NEW JERSEY", "NEW MEXICO", "NEW YORK", "NORTH CAROLINA", "OHIO", "OKLAHOMA", "OREGON", "PENNSYLVANIA", "SOUTH CAROLINA", "VERMONT", "WISCONSIN")`).

Fruit

Fruit has a single string of **STRAWBERRY**, which shows that all the data is based on this fruit.

crop_type

crop_type also has a single string, **ORGANIC**, which shows that the entirety of the production data is based on organic strawberries.

Totals

Totals holds three values: `c("OPERATIONS WITH SALES", "SALES", ",", "PRODUCTION")`. The **SALES** string represents the sales of strawberries, **OPERATIONS WITH SALES** represents how many operating strawberry production with intent to sell, and **PRODUCTION** represents the amount of strawberries produced.

Fresh Market

Fresh Market holds two values: **OPERATIONS WITH SALES** and **SALES**. The definition of both of these values are the same as the **Totals** column.

Process Market

Process Market has the same strings as **Fresh Market**.

Metric

Metric has the following strings: `c("", "$", "CWT")`.

The empty string holds no values because that row did not need a metric to help describe the data. **\$** represents that the metric for the following **Value** column is in US Dollars. **CWT** is weight in 100's

[[CWT](#)].

Value

The **Value** column holds numeric values that correspond with the strings in **Totals**, **Fresh Market**, and **Process Market**, as well as the **Metric** column.

CV (%)

Finally, the CV (%) column holds the co-efficients of variance of the numeric values in the Value column.

Missing Values

All rows with missing values in the Value column were omitted. The missing values represented values that were omitted by the state upon census data collection. These values have no purpose in the data analysis.

Categorizing Values

All columns, but Value and CV (%) hold nominal variables. Both the Value column and CV (%) hold interval variables.

Data Visualization

Questions

After analyzing the columns and values of `strwb_census`, I developed the following questions:

1. What state held the most organic operational strawberry sellers?
2. What states made the most money producing strawberries?
3. What states produced the most strawberries?

These questions will be individually answered below via data visualization.

What state held the most organic operational strawberry sellers?

Figure 3 below shows all the US states but California who reported Census data from 2019 to 2021 for their organic strawberry operational sellers. California was moved to Figure 5 as it was a significantly high outlier from the other states in operational sellers. Connecticut was the only state that had data for both 2019 and 2021, Alabama only reported data for 2019, and the remaining states only reported for 2021. The state with the most organic sellers was by far California ($n = 142$). Next was Oregon ($n = 26$), but was also significantly lower than California. The least number of sellers were located in Alabama ($n = 2$) with Georgia ($n = 4$) and Iowa ($n = 4$) following the next least.

Figure 3. States* and Organic Operational Strawberry Sales

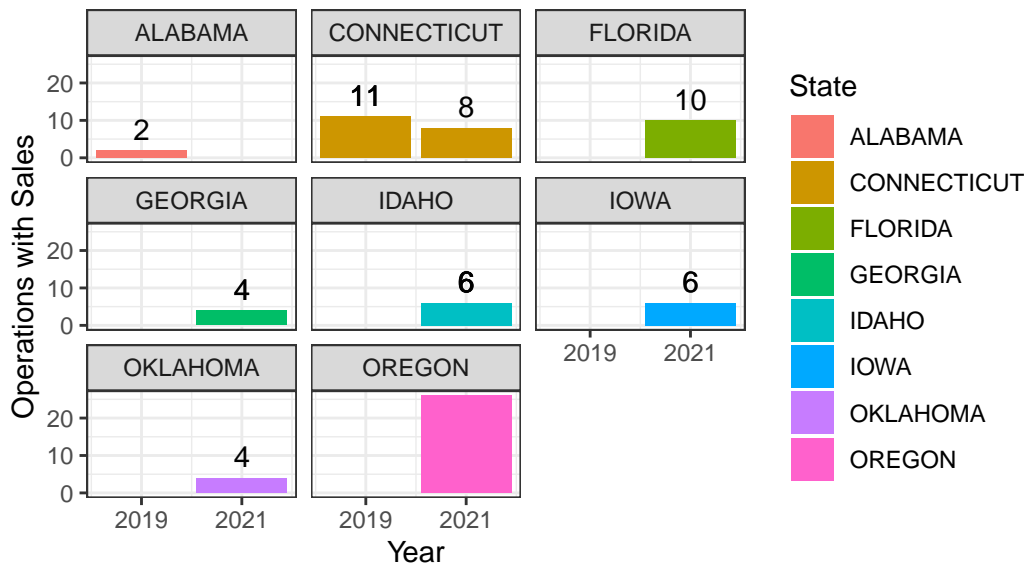
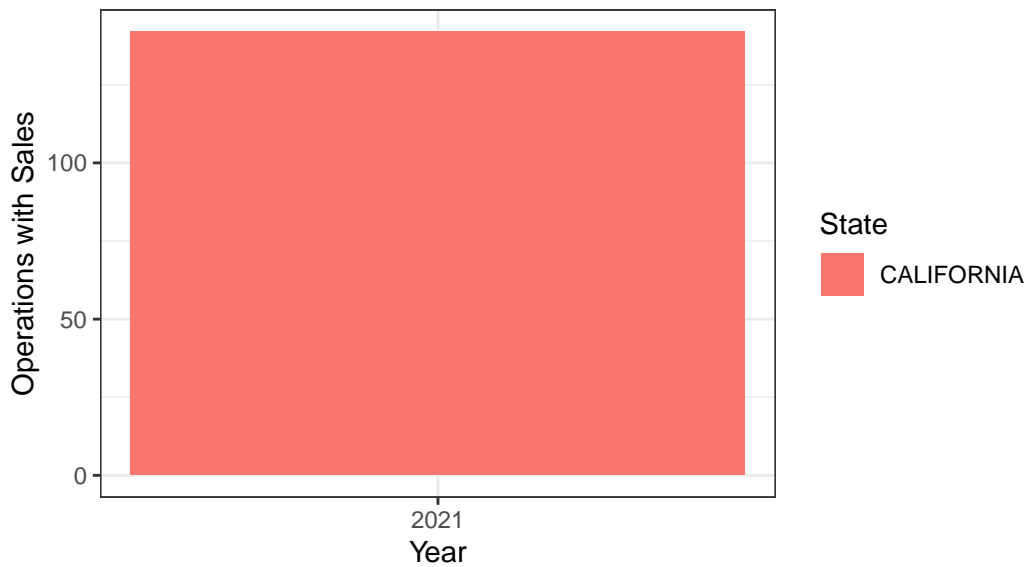


Figure 3. California* and Organic Operational Strawberry Sales



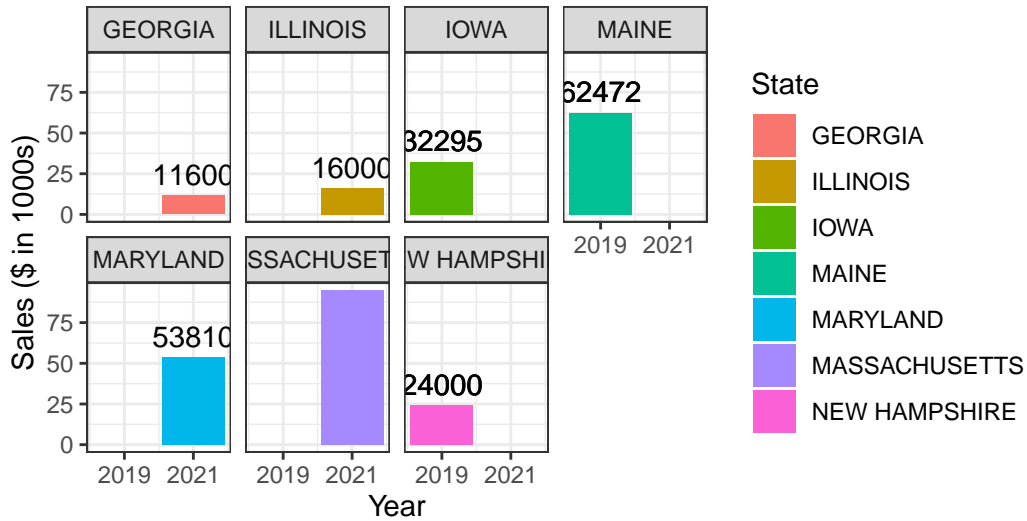
What states made the most money producing strawberries?

In Figure 4 below, there are varying amounts of money made on organic strawberry sales for

each state who provided data. California's organic strawberry sales were moved to Figure 5 due to it being an extreme outlier with the highest sales high above every other state (n = 311,784,980). Massachusetts is the second highest in sales (n = 94,827). Georgia made the least in sales (n = 11,600), and Illinois was the second least (n = 16,000).

Figure 4. States* and Organic Strawberry Sales

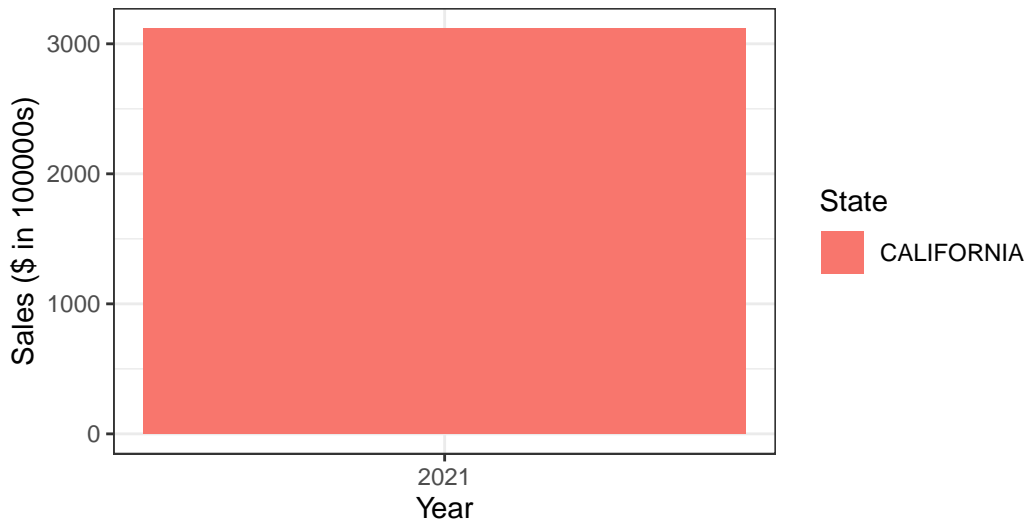
in US Dollars



*California was excluded due to extremely higher sales

Figure 5. California* and Organic Strawberry Sales

in US Dollars

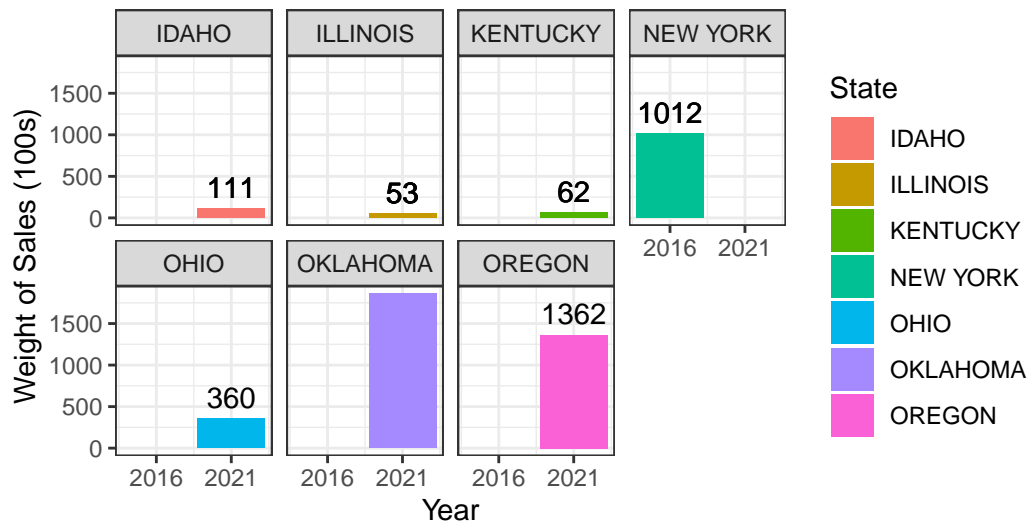


*Only California was included, as it is an outlier from the other states

What states produced the most strawberries?

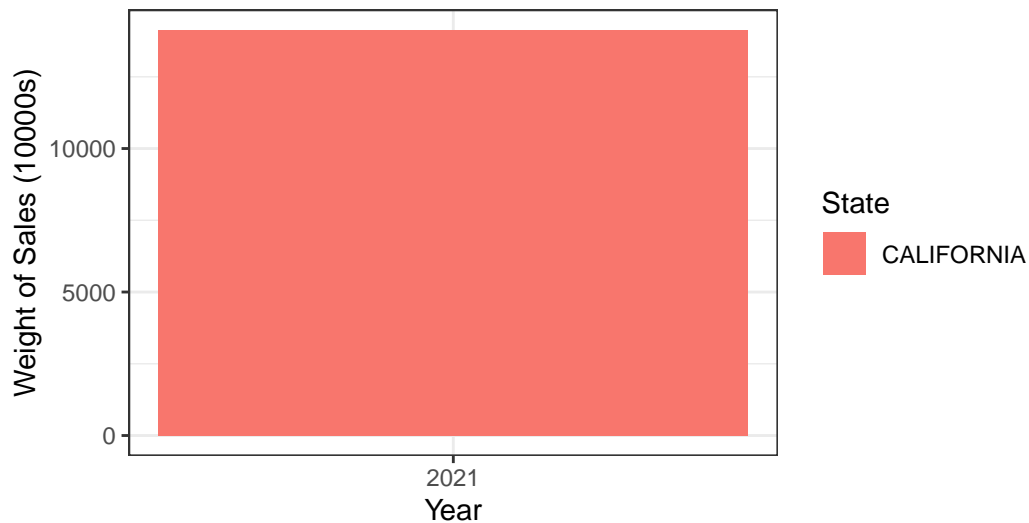
On pattern with the other questions, all states but California were included in Figure 6 for the states who produced the most organic strawberry in hundredweight. Figure 7 holds the organic strawberry weight produced in tens of thousands. California has the highest hundred-weight produced ($n = 1,412,627$). The next highest was Oklahoma ($n = 1,858$), which is still significantly lower than California. The lowest in organic strawberry production was Illinois ($n = 53$), and the next lowest was Kentucky ($n = 62$).

Figure 6. States* and Organic Strawberry Sales
in US Dollars



*California was excluded due to being an extreme outlier

Figure 7. California* and Organic Strawberry Sales
in US Dollars



*California was only included, as it was an extreme outlier

strwb_survey_mkt

Columns & Values

There are five columns in `strwb_survey_mkt`: `Year`, `State`, `measurement`, `avg`, `type`, `fertilizer_type`, and `Value`. The columns represent the fertilizer type used for each year for each state and the amount of it that was used.

Year

`Year` holds two year values: 2018 and 2019. This represents the year that the following values took place.

State

`State` has two US state values: `CALIFORNIA` and `FLORIDA`. Each of these represent the US state that returned data for the selected columns included in this data frame.

measurement

measurement has the following three values : `c("MEASURED IN LB", "MEASURED IN LB / ACRE / APPLICATION", "MEASURED IN LB / ACRE / YEAR", "MEASURED IN NUMBER")`. **MEASURED IN LB** represents that the following **Value** is in pounds (lbs). **MEASURED IN LB / ACRE / APPLICATION** is that the **Value** was measured in lbs divided by acreage of the farm and by the amount applied when used.

avg

avg holds NA and **avg** values. **avg** represents when an average was taken, and NA is present when an average was not needed for the type of measurement.

type

type holds the single string of **FERTILIZER**, which represents that all the rows hold data related to fertilizers.

fertilizer_type

fertilizer_type holds the following strings of fertilizer types used on the strawberry crops: `c("NITROGEN", "PHOSPHATE", "POTASH", "SULFUR")`.

Value

Value which holds numeric values that correspond with the **measurement** and **avg** columns to show the value related to the fertilizer usage.

Missing Values

All rows with data almost identical to **strwb_census** were removed. Additionally, all rows with NA values in the **Value** column were omitted, as they did not hold any meaningful data.

Categorizing Variables

All columns but **Value** and hold nominal variables. The **Value** column holds interval variables.

Data Visualization

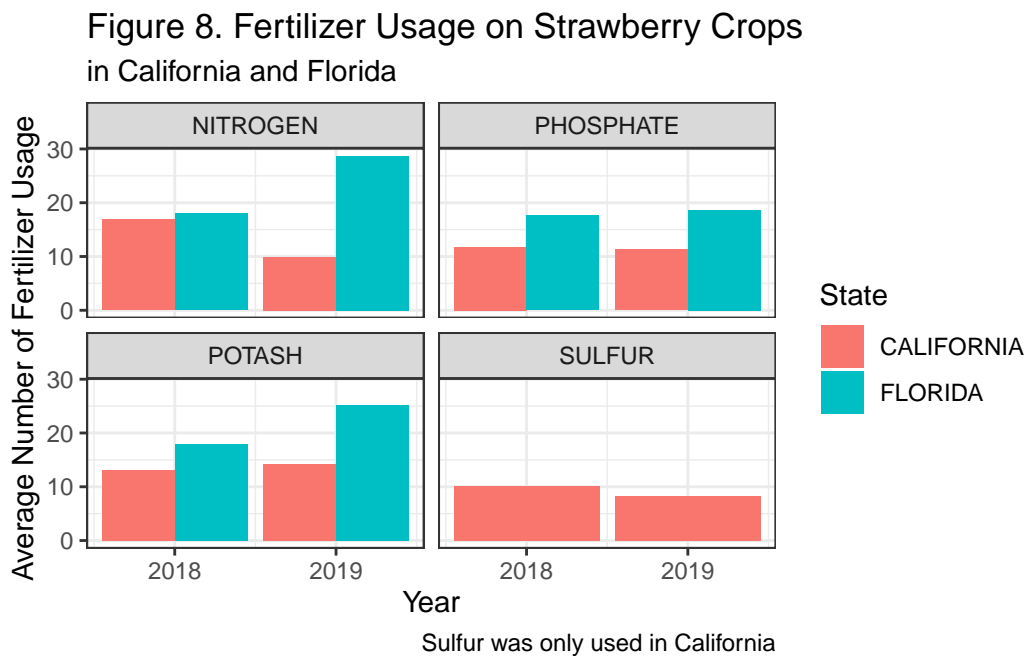
Questions

The following questions will be answered via data visualization below:

1. What state used what fertilizer types? What fertilizers were used the most?
2. What state used the most pounds of fertilizer?
3. What state used the most pounds per an acre per application of fertilizer? What fertilizer was used the most?

What state used what fertilizer types?

As shown in Figure 8 below, California used all four fertilizers on their crops (nitrogen, phosphate, potash, sulfur), and Florida used all but sulfur. The fertilizer used the most was nitrogen for both California ($n = 16.9$) and Florida ($n = 28.7$). Next most used was potash for both California ($n = 14.3$) and Florida ($n = 25.2$). Florida used more fertilizer than California for all three fertilizers they both used.



What state used the most pounds of fertilizer?

Figure 9 shows the pounds (lbs) of fertilizer by type for the state of California, and Figure 10 shows such for Florida. California ($N = 31,289,000$) used far more lbs of fertilizer than Florida ($N = 1,146,000$) between the years of 2018 and 2019. California used far more lbs of all four fertilizers in 2018 than in 2019. Florida had the opposite with more fertilizer used in 2019 than 2018.

Figure 9. Pounds of Fertilizer Used on Strawberries in California

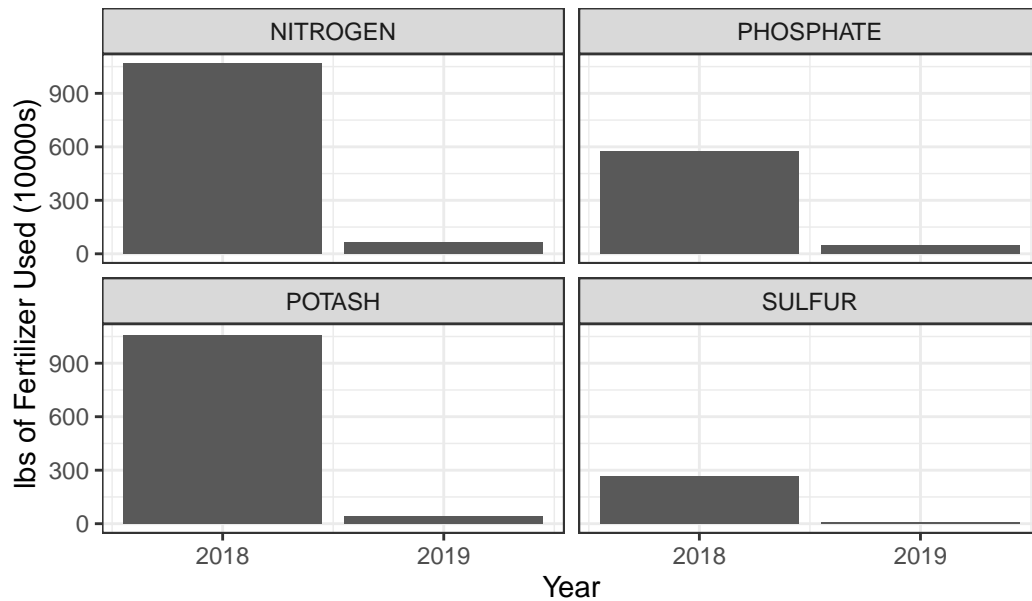
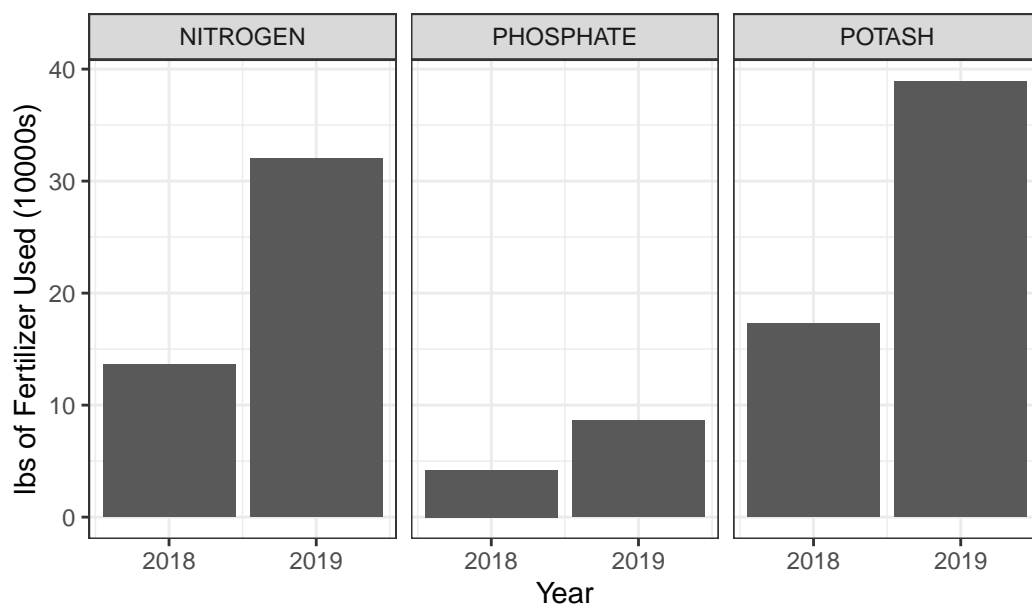


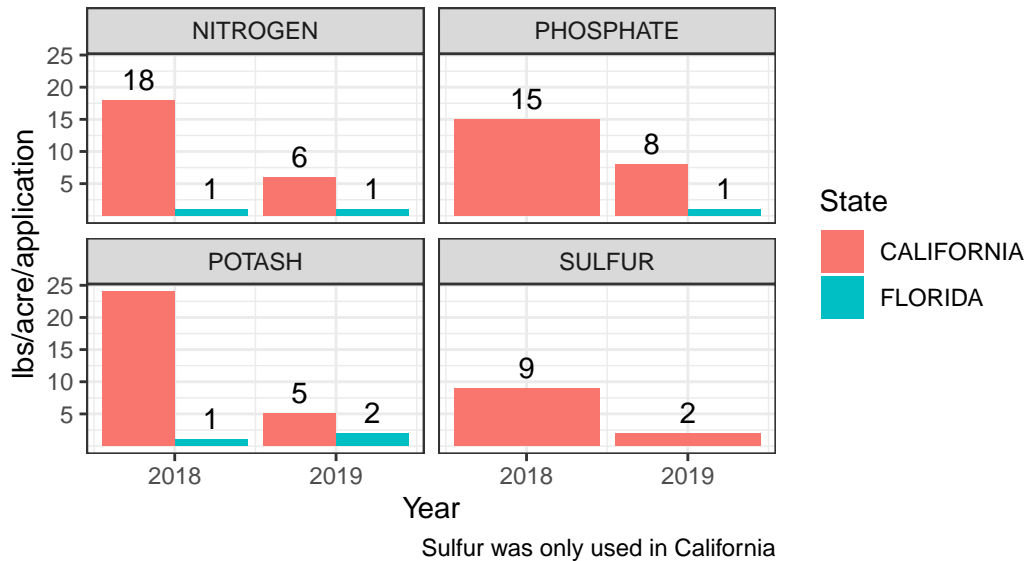
Figure 10. Pounds of Fertilizer Used on Strawberries in Florida



What state used the most pounds per an acre per application of fertilizer?

Figure 11 below shows that California (Mean = 11) used significantly more lbs of fertilizer per an acre and application than Florida (Mean = 1). The most used pesticide for California (n = 24) and Florida (n = 2) was potash.

Figure 11. Pounds of Fertilizer Used Per Acre Per Application in Florida and California



strwb_survey_treat

Columns & Values

The columns in `strwb_survey_treat` are as follows: `Year`, `State`, `chem_type`, `strwb_treatment`, `PC#`, `CAS#`, `toxicity`. Each of the values in the columns are explained below.

`Year` represents the year in which the values in the row are from. The years are as follows: `c(2021, 2019, 2018, 2016)`.

`State` has the following strings: `c("CALIFORNIA", "FLORIDA", "OREGON", "WASHINGTON")`. Each as these show what US state the survey data was retrieved from.

`chem_type` holds strings representing categories of pesticides used: `c("FUNGICIDE", "HERBICIDE", "INSECTICIDE", "OTHER")`.

`strwb_treatment` represents the chemical or bacteria used on the strawberry crops: `c("AZOXYSTROBIN", "BACILLUS AMYLOLIQUEFAC F727", "BACILLUS AMYLOLIQUEFACIENS MBI 600", "BACILLUS AMYLOLIQUEFACIENS STRAIN D747", "BACILLUS PUMILUS", "BACILLUS SUBTILIS", "BLAD", "BORAX DECAHYDRATE", "BOSCALID", "BT SUBSP KURSTAKI EVB-113-19", "CAPTAN", "COPPER OCTANOATE", "CYFLUFENAMID", "CYPRODINIL", "DIFENOCONAZOLE", "FENHEXAMID", "FLUDIOXONIL", "FLUOPYRAM", "FLUXAPYROXAD", "FOSETYL-AL", "ISOFETAMID", "MEFENOXAM", "MONO-POTASSIUM SALT", "MYCLOBUTANIL",`

"PENTHIOPYRAD", "POLYOXIN D ZINC SALT", "POTASSIUM BICARBON.", "PROPI-
 CONAZOLE", "PYRACLOSTROBIN", "PYRIMETHANIL", "QUINOLINE", "STREPTO-
 MYCES LYDICUS", "SULFUR", "TETRACONAZOLE", "THIOPHANATE-METHYL",
 "THIRAM", "TRIFLOXYSTROBIN", "TRIFLUMIZOLE", "CARFENTRAZONE-
 ETHYL", "FLUMIOXAZIN", "GLYPHOSATE ISO. SALT", "GLYPHOSATE POT.
 SALT", "NAPROPAMIDE", "OXYFLUORFEN", "PARAQUAT", "PENDIMETHALIN",
 "ABAMECTIN", "ACEQUINOCYL", "ACETAMIPRID", "AZADIRACHTIN", "BEAU-
 VERIA BASSIANA", "BIFENAZATE", "BIFENTHRIN", "BT KURSTAK ABTS-1857",
 "BT KURSTAKI ABTS-351", "BT KURSTAKI EG7841", "BT KURSTAKI SA-11", "BT
 SUB AIZAWAI GC-91", "BUPROFEZIN", "BURKHOLDERIA A396 CELLS & ME-
 DIA", "CANOLA OIL", "CHLORANTRANILIPROLE", "CHROMOBAC SUBTSUGAE
 PRAA4-1 CELLS AND SPENT MEDIA", "CYANTRANILIPROLE", "CYFLUMETOFEN",
 "DIAZINON", "ETOXAZOLE", "FENBUTATIN-OXIDE", "FENPROPATHRIN", "FENPY-
 ROXIMATE", "FLONICAMID", "FLUPYRADIFURONE", "HELICOVERPA ZEA NPV",
 "HEXYTHIAZOX", "IMIDACLOPRID", "MALATHION", "METHOXYFENOZIDE",
 "NALED", "NEEM OIL", "NOVALURON", "PETROLEUM DISTILLATE", "PIPERONYL
 BUTOXIDE", "POTASSIUM SALTS", "PYRETHRINS", "PYRIDABEN", "PYRIPROX-
 YFEN", "SPINETORAM", "SPINOSAD", "SPIROMESIFEN", "THIAMETHOXAM",
 "ACIBENZOLAR-S-METHYL", "CAPRIC ACID", "CAPRYLIC ACID", "CAPSICUM
 OLEORESIN EXTRACT", "CHLOROPICRIN", "DICHLOROPROPENE", "FLUTRI-
 AFOL", "GARLIC OIL", "HYDROGEN PEROXIDE", "IRON PHOSPHATE", "METAM-
 POTASSIUM", "MINERAL OIL", "PAECILOMYCES FUMOSOR", "PEROXYACETIC
 ACID", "POTASSIUM SILICATE", "PSEUDOMONAS CHLORORAPHIS STRAIN
 AFS009", "REYNOUtria SACHALINE", "PYDIFLUMETOFEN", "CLETHODIM",
 "COPPER ETHANOLAMINE", "DIMETHENAMID", "FLUROXYPYR 1-MHE",
 "HALOSULFURON-METHYL", "KANTOR", "CARBARYL", "FENAZAQUIN", "SUL-
 FOXAFLO", "CYTOKININS", "ETHEPHON", "INDOLEBUTYRIC ACID", "BACILLUS
 SUBT. GB03", "COPPER HYDROXIDE", "TRICHODERMA HARZ.", "GLUFOSINATE-
 AMMONIUM", "SULFENTRAZONE", "CHLORPYRIFOS", "SOYBEAN OIL", "ZETA-
 CYPERMETHRIN", "AUREOBASIDIUM PULLULANS DSM 14940", "AUREOBASID-
 IUM PULLULANS DSM 14941", "BT KURSTAKI SA-12", "GLIOCLADIUM VIRENS",
 "METALDEHYDE", "METAM-SODIUM", "TRICHODERMA VIRENS STRAIN G-41",
 "COPPER CHLORIDE HYD.", "DODINE", "FLUTOLANIL", "CYPERMETHRIN",
 "ALKYL. DIM. BENZ. AM", "DECYLDIMETHYLOCTYL", "DIDECYL DIM. AMMON.",
 "DIMETHYLDIOCTYL", "IPRODIONE", "EMAMECTIN BENZOATE", "LAMBDA-
 CYHALOTHRIN", "SPIROTETRAMAT", "MUSTARD OIL", "DIMETHYL DISULFIDE
 (DMDS)", "COPPER OXIDE", "AMMONIUM PELARGONATE", "FLUBENDIAMIDE",
 "METHYL BROMIDE", "CHLOROTHALONIL", "CYAZOFAMID", "MANCOZEB", "EN-
 DOSULFAN", "CAPSAICIN", "HARPIN A B PROTEIN", "CLOPYRALID MONO SALT",
 "SIMAZINE", "TERBACIL", "FERRIC SODIUM EDTA", "CLOMAZONE").

PC# represents the treatment identification number, Pesticide Chemical Code. These are nu-
 meric values.

CAS# either had the Chemical Abstracts Service number or is indicated as **Bacteria**, as bacterium do not have CAS#s.

Finally, **toxicity** holds the following strings: c(“Unlikely to present acute hazard”, “No significant acute toxicity”, “Slightly hazardous”, “Moderately hazardous”, “Fatal if inhaled”, “Toxic if inhaled”, “Highly hazardous”, “Unknown”, “Extremely hazardous”). These are based on the World Organization Health Organization’s Pesticide Toxicity Classification [WHO, 2019] (see more information above).

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