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.

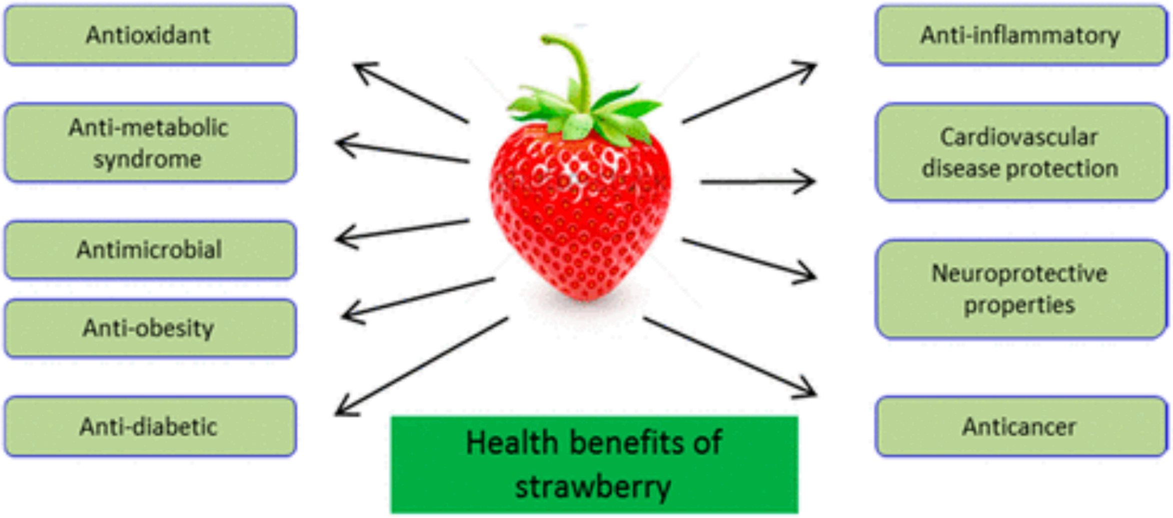


Figure 1: Health benefits of strawberries (Afrin et al., 2016)

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.

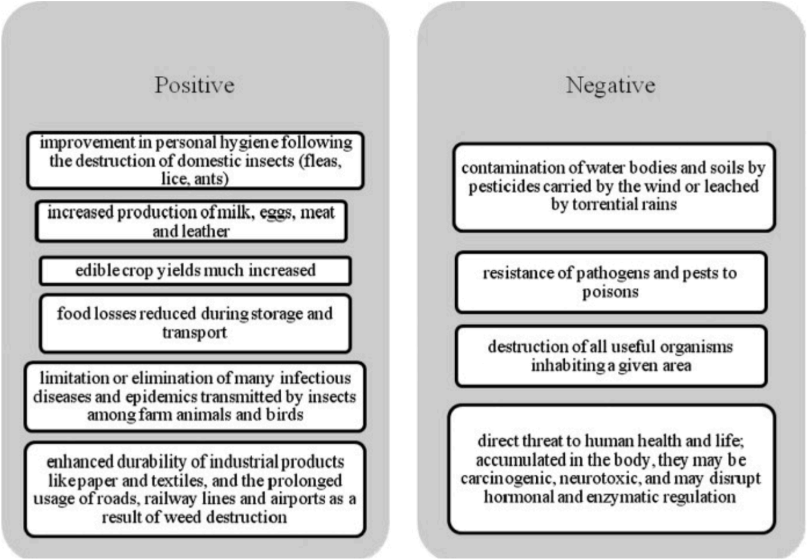
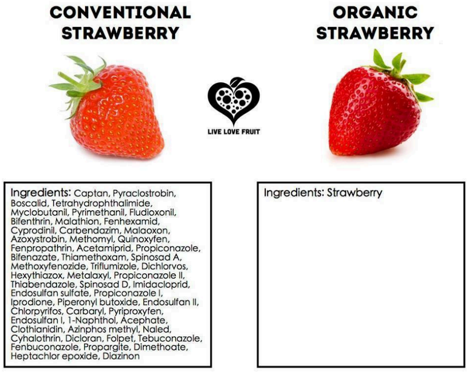

Positive
improvement in personal hygiene following the destruction of domestic insects (fleas, lice, ants)
increased production of milk, eggs, meat and leather
edible crop yields much increased
food losses reduced during storage and transport
limitation or elimination of many infectious diseases and epidemics transmitted by insects among farm animals and birds
enhanced durability of industrial products like paper and textiles, and the prolonged usage of roads, railway lines and airports as a result of weed destruction
Negative
contamination of water bodies and soils by pesticides carried by the wind or leached by torrential rains
resistance of pathogens and pests to poisons
destruction of all useful organisms inhabiting a given area
direct threat to human health and life; accumulated in the body, they may be carcinogenic, neurotoxic, and may disrupt hormonal and enzymatic regulation

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.



Ingredients: Captan, Pyraclostrobin, Boscalid, Tetrahydrophthalimide, Myclobutanil, Pyrimethanil, Fludioxonil, Bifenthrin, Malathion, Fenhexamid, Cyprodinil, Carbendazim, Malaoxon, Azoxystrobin, Methomyl, Quinoxyfen, Fenpropathrin, Acetamiprid, Propiconazole, Bifenazate, Thiamethoxam, Spinosad A, Methoxyfenozide, Triflumizole, Dichlorvos, Hexythiazox, Metalaxyl, Propiconazole II, Thiabendazole, Spinosad D, Imidacloprid, Endosulfan sulfate, Propiconazole I, Iprodione, Piperonyl butoxide, Endosulfan II, Chlorpyrifos, Carbaryl, Pyriproxyfen, Endosulfan I, 1-Naphthol, Acephate, Clothianidin, Azinphos methyl, Naled, Cyhalothrin, Dicloran, Folpet, Tebuconazole, Fenbuconazole, Propargite, Dimethoate, Heptachlor epoxide, Diazinon

Ingredients: Strawberry

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 processed (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,~
$ `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~
```

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,~
$ 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 - 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,~
```

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 unneccesary 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 paren on the TOTAL values in the chemical column.

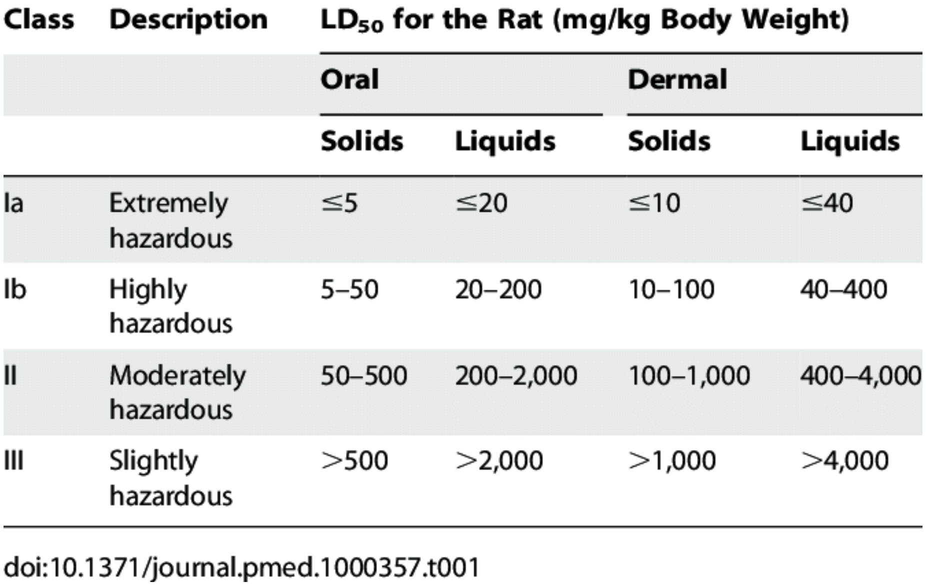
Then, I removed the commas and changed the values in Value to numbers instead of strings. This introduced NA values, and I dropped all the columns with NA.

Finally, to rename temp3 to measurement and temp4 to avg.

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-Cyfluefenamid], [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 SUBTSUGAE 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 reprents 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:

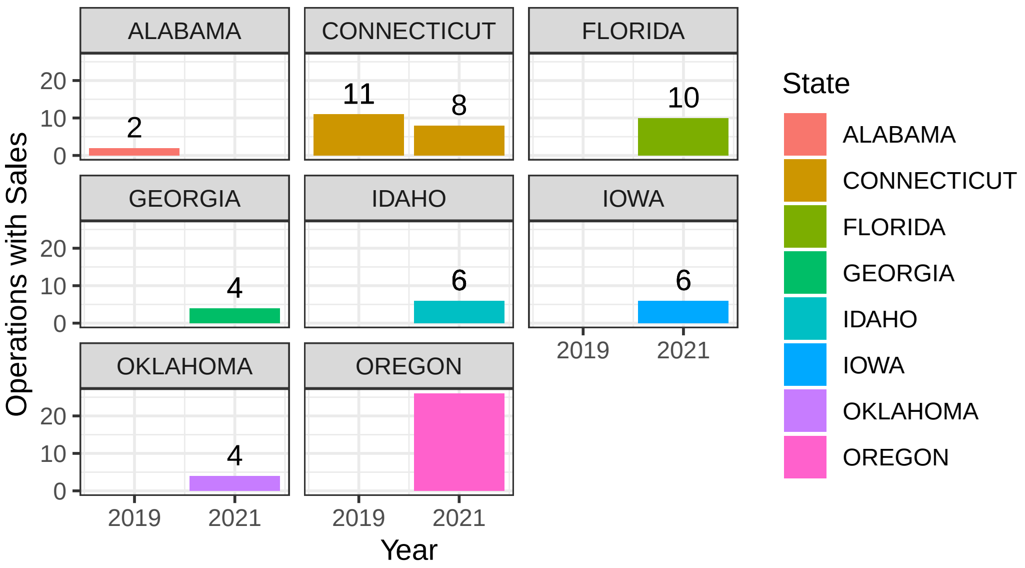
1. What state held the most organic operational strawberry sellers?
2. What states made the most money producing strawberries?
3. What states produced the most strawberries?

These questions will be individually answered below via data visualization.

What state held the most organic operational strawberry sellers?

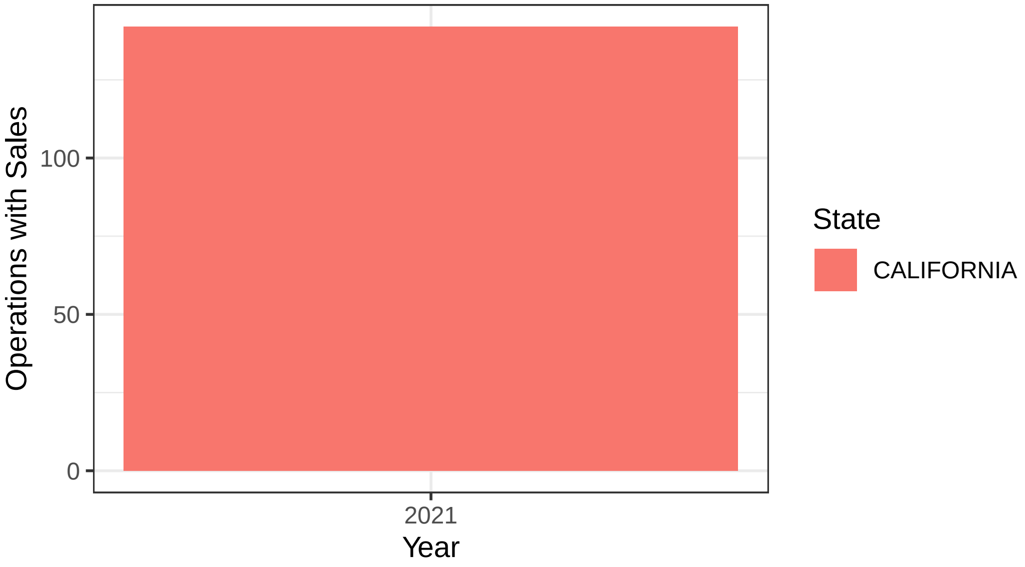
Figure 3 below shows all the US states but California who reported Census data from 2019 to 2021 for their organic strawberry operational sellers. California was moved to Figure 5 as it was a significantly high outlier from the other states in operational sellers. Connecticut was the only state that 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



*California was excluded due to extremely higher sales

Figure 3. California* and Organic Operational Strawberry Sales

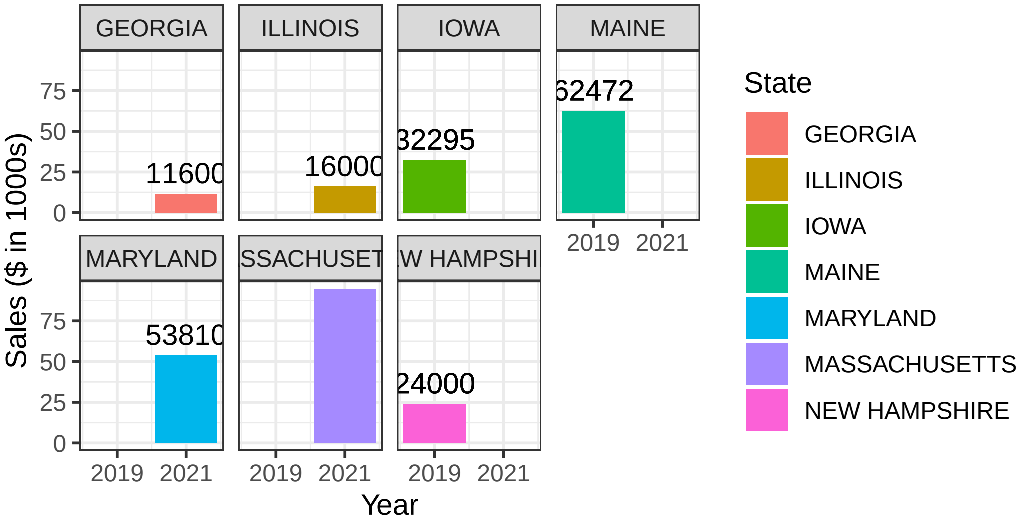


*California was only included, as it was an outlier for the other data

What states made the most money producing strawberries?

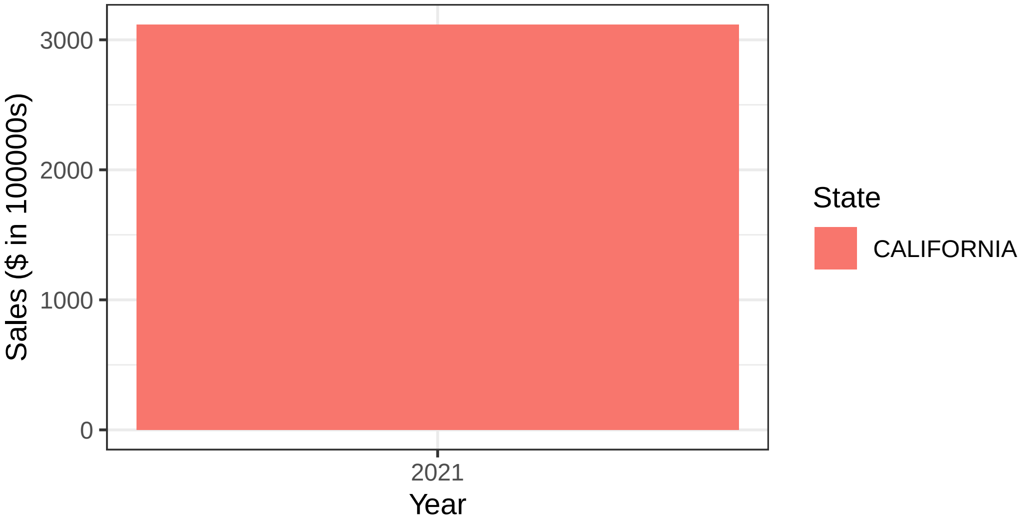
In Figure 4 below, there are varying amounts of money made on organic strawberry sales for each state who provided data. California's organic strawberry sales were moved to Figure 5 due to it being an extreme outlier with the highest sales high above every other state (n = 311,784,980). Massachusetts is the second highest in sales (n = 94,827). Georgia made the least in sales (n = 11,600), and Illnois 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



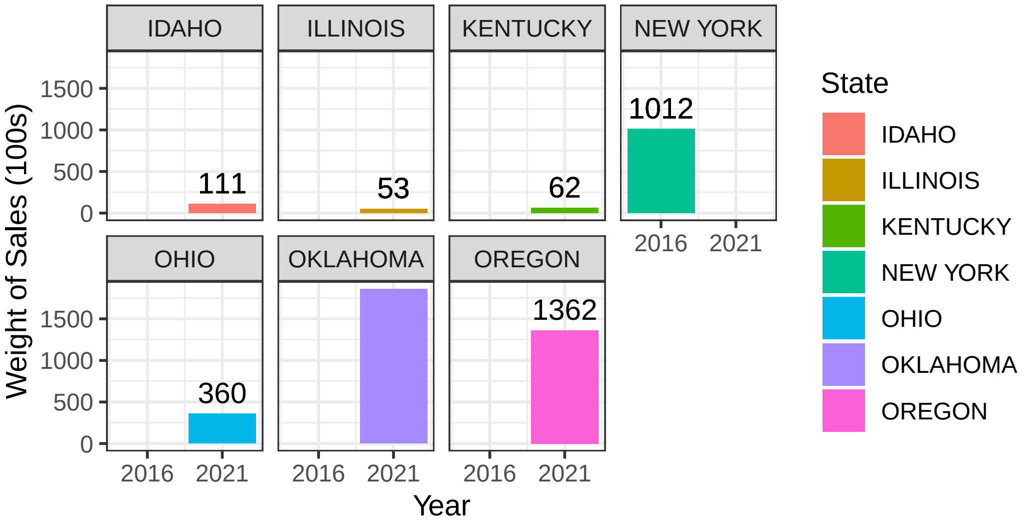
*Only California was included, as it is an outlier from the other states

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 hundredweight 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 Illnois (n = 53), and the next lowest was Kentucky (n = 62).

Figure 6. States* and Organic Strawberry Sales

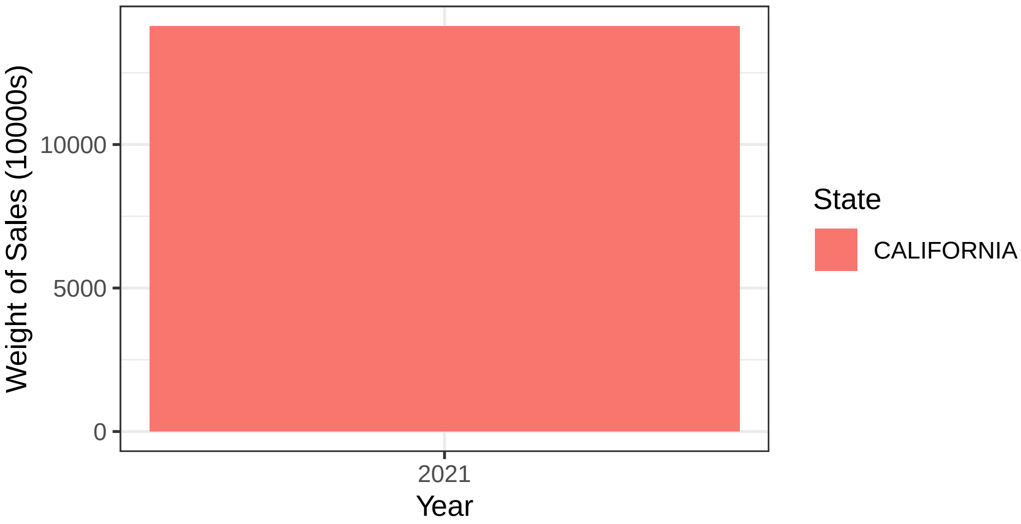
in US Dollars



*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:

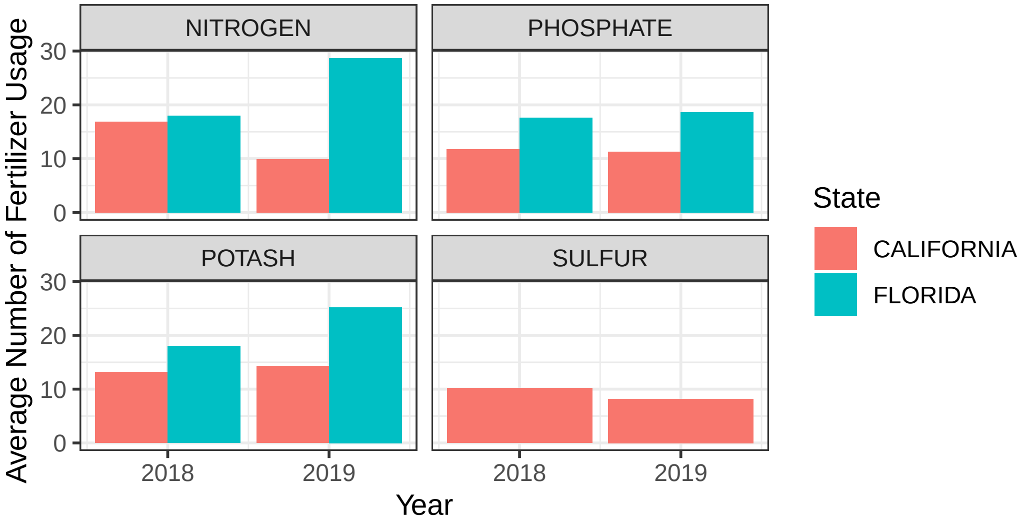
1. What state used what fertilizer types? What fertilizers were used the most?
2. What state used the most pounds of fertilizer?
3. What state used the most pounds per an acre per application of fertilizer? What fertilizer was used the most?

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.

Figure 8. Fertilizer Usage on Strawberry Crops

in California and Florida



Sulfur was only used in California

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 Californi

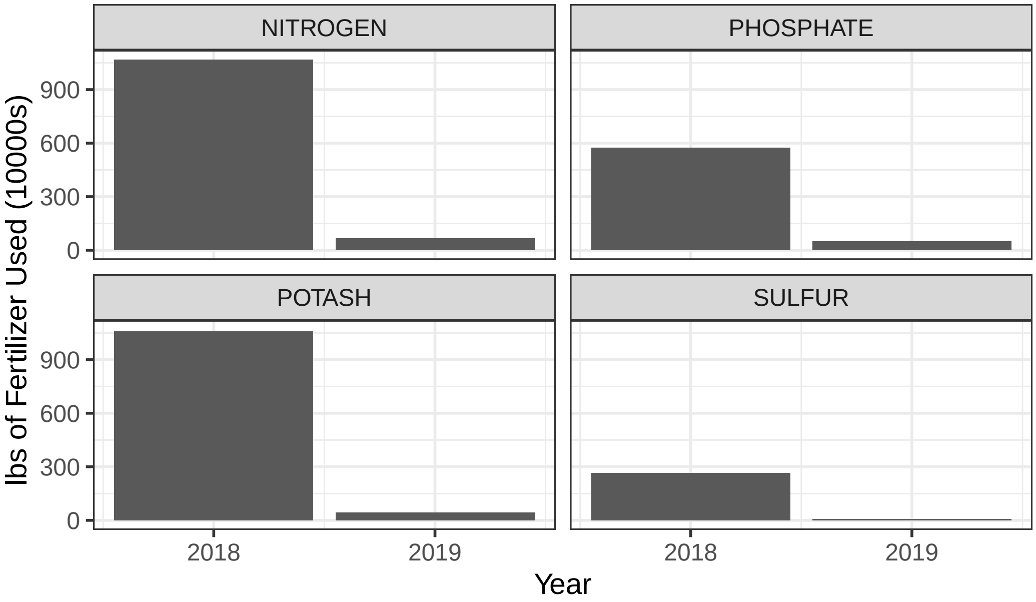
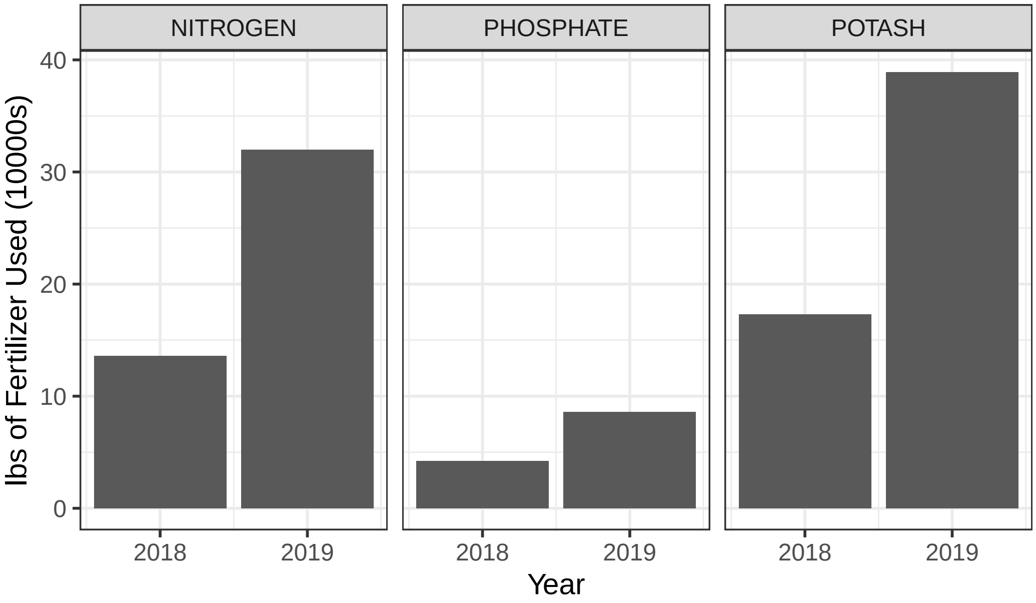


Figure 10. Pounds of Fertilizer Used on Strawberries in Florida

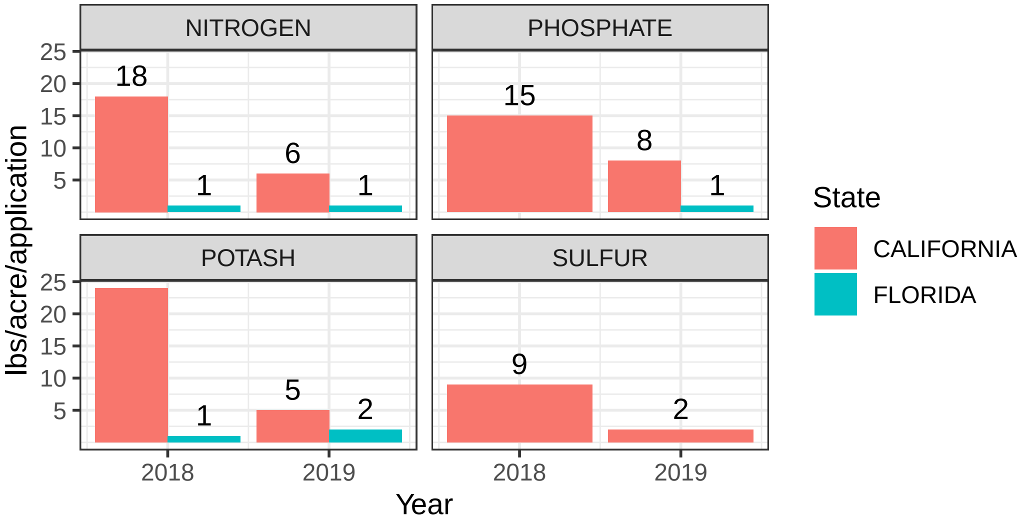


What state used the most pounds per an acre per application of fertilizer?

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



Sulfur was only used in California

strwb_survey_treat

Columns & Values

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

Year

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

State

`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

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

strwb_treatment

`strwb_treatment` represents the chemical or bacteria used on the strawberry crops: c("AZOXYSTROBIN", "BORAX DECAHYDRATE", "BOSCALID", "CAPTAN", "CYFLUFENAMID", "CYPRODINIL", "FENHEXAMID", "FLUDIOXONIL", "FLUOPYRAM", "FLUXAPYROXAD", "MEFENOXAM", "MYCLOBUTANIL", "PENTHIOPYRAD", "POLYOXIN D ZINC SALT", "POTASSIUM BICARBON.", "PROPICONAZOLE", "PYRACLOSTROBIN", "PYRIMETHANIL", "QUINOLINE", "SULFUR", "TETRACONAZOLE", "THIOPHANATE-METHYL", "THIRAM", "TOTAL", "TRIFLOXYSTROBIN", "TRIFLUMIZOLE", "FLUMIOXAZIN", "OXYFLUORFEN", "PENDIMETHALIN", "ABAMECTIN", "ACEQUINOCYL", "ACETAMIPRID", "AZADIRACHTIN", "BIFENAZATE", "BIFENTHRIN", "CHLORANTRANILIPROLE", "CYANTRANILIPROLE", "CYFLUMETOFEN", "FENPROPATHRIN", "FENPYROXIMATE", "FLONICAMID", "FLUPYRADIFURONE", "HEXYTHIAZOX", "IMIDACLOPRID", "MALATHION", "METHOXYFENOZIDE", "NALED", "NEEM OIL", "NOVALURON", "PYRETHRINS", "SPINETORAM", "SPINOSAD", "SPIROMESIFEN", "THIAMETHOXAM", "CHLOROPICRIN", "DICHLOROPROPENE", "FLUTRIAFOL", "HYDROGEN PEROXIDE", "METAM-POTASSIUM", "PEROXYACETIC ACID", "REYNOUTRIA SACHALINE", "BACILLUS AMYLOLIQUEFACIENS STRAIN D747", "BACILLUS SUBTILIS", "BT KURSTAK ABTS-1857", "BT KURSTAKI ABTS-351", "BT KURSTAKI SA-11", “CHROMOBAC SUBTSUGAE PRAA4-1 CELLS AND SPENT MEDIA”, “BLAD”, “DIFENOCONAZOLE”, “FOSETYL-AL”, “CARFENTRAZONE-ETHYL”, “ETOXAZOLE”, “PIPERONYL BUTOXIDE”, “PYRIPROXYFEN”, “SULFOXAFLOR”, “IRON PHOSPHATE”, “METAM-SODIUM”, “BT SUBSP KURSTAKI EVB-113-19”, “BT SUB AIZAWAI GC-91”, “BURKHOLDERIA A396 CELLS & MEDIA”, “BACILLUS PUMILUS”, “ISOFETAMID”, “SULFENTRAZONE”).

PC

`PC#` represents the treatment identification number, Pesticide Chemical Code. These are numeric values.

CAS

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

measurement

`measurement` has the following strings that represents the metric that the values were measured in: c(” MEASURED IN LB”, ” MEASURED IN LB / ACRE / APPLICATION”, ” MEASURED IN LB / ACRE / YEAR”, ” MEASURED IN NUMBER”).

avg

The `avg` column has both `NA` values and the string `avg`, which represents if the numeric value it is describing is an average or not.

CAS

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

toxicity

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

Value

Finally, the `Value` column holds numeric values that are described by the `avg` and `measurement` columns.

Missing Values

All missing values in `PC#` were dropped,

Categorizing Variables

THe values in `toxicity` can be ranked high to low, therefore they are categorical variables. `CAS#`, `strwb_treatment`, `chem_type`, `State`, `Year`, `avg`, `measurement` and `PC#` are all nominal variables. `Value` holds interval variables.

Data Visualization

Questions

1. What pesticide category was used the most?
2. What pesticides were most toxic?

What pesticide category was used the most?

```r
new_data <- strwb_survey_treat |>
  filter(strwb_treatment == "TOTAL" & State != "CALIFORNIA" & State != "FLORIDA")

new_data$Value <- as.numeric(new_data$Value)

ggplot(data = new_data,
       mapping = aes(x = Year, y = (Value/100), fill = State)) +
  geom_bar(stat = "identity", position = "dodge") +
  labs(
    title = "Figure 12. Pounds of Different Pesticide Categories Used",
    subtitle = "in Oregon and Washington",
    x = "Year",
    y = "lbs (100s)"
  ) +
  theme_bw() +
  facet_wrap(~chem_type) +
  scale_x_continuous(breaks = 2016)
```

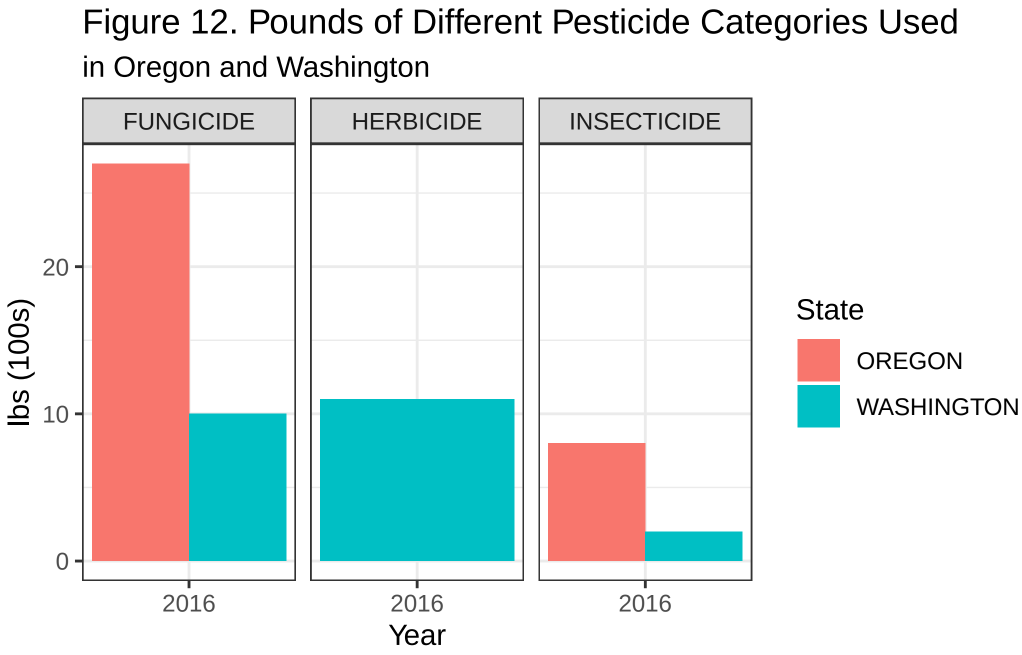


Figure 12. Pounds of Different Pesticide Categories Used
in Oregon and Washington

```
new_data2 <- strwb_survey_treat |>
  filter(strwb_treatment == "TOTAL" & State == "CALIFORNIA")

new_data2$Value <- as.numeric(new_data2$Value)

ggplot(data = new_data2,
       mapping = aes(x = Year, y = (Value/100000))) +
  geom_bar(stat = "identity", position = "dodge") +
  labs(
    title = "Figure 12. Pounds of Different Pesticide Categories Used",
    subtitle = "in California",
    x = "Year",
    y = "lbs (1000000s)"
  ) +
  theme_bw() +
  scale_x_continuous(breaks = c(2016, 2018, 2019, 2021)) +
  facet_wrap(~chem_type)
```

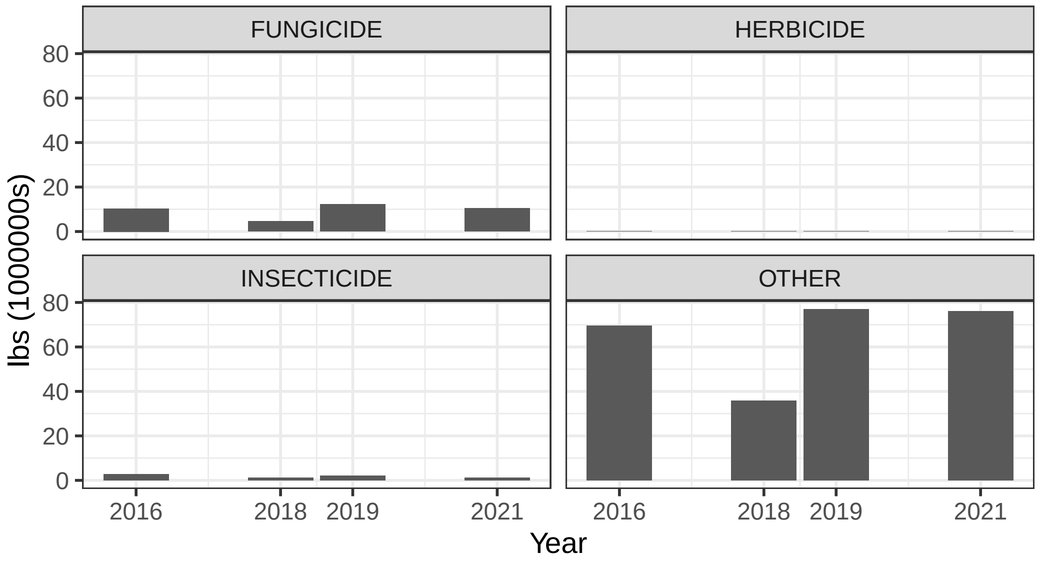


Figure 12. Pounds of Different Pesticide Categories Used

in California

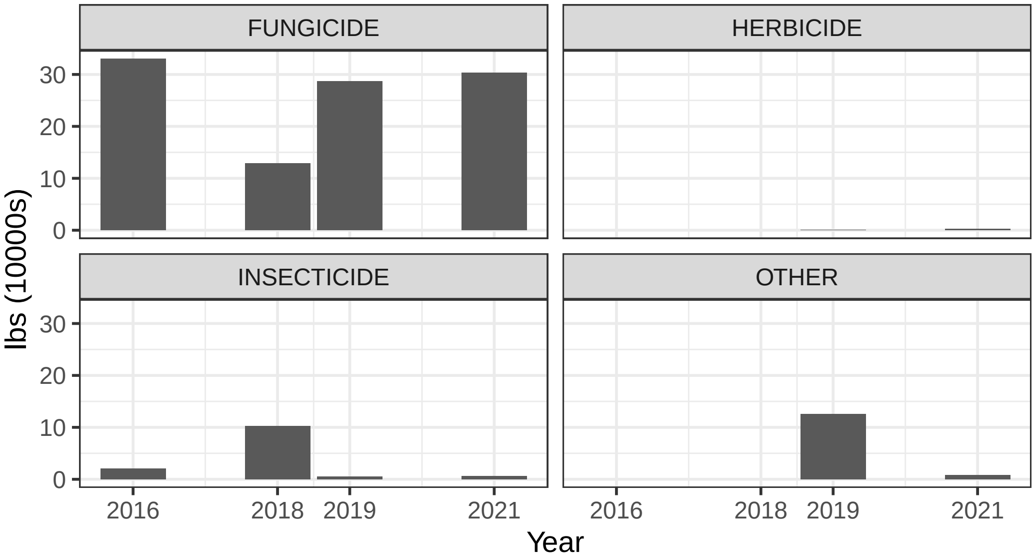
```
new_data3 <- strwb_survey_treat |>
  filter(strwb_treatment == "TOTAL" & State == "FLORIDA")

new_data3$Value <- as.numeric(new_data3$Value)

ggplot(data = new_data3,
       mapping = aes(x = Year, y = (Value / 10000))) +
  geom_bar(stat = "identity", position = "dodge") +
  labs(
    title = "Figure 12. Pounds of Different Pesticide Categories Used",
    subtitle = "in Florida",
    x = "Year",
    y = "lbs (10000s)"
  ) +
  theme_bw() +
  scale_x_continuous(breaks = c(2016, 2018, 2019, 2021)) +
  facet_wrap(~chem_type)
```

Figure 12. Pounds of Different Pesticide Categories Used

in Florida



What pesticides were most toxic?

```r
new_data11 <- strwb_survey_treat |>
  group_by(toxicity)

new_data11 <- new_data11 |>
  mutate(toxicity = case_when(
    strwb_treatment %in% c("GARLIC OIL") ~ "Extremely hazardous",
    strwb_treatment %in% c("ABAMECTIN", "DODINE", "MINERAL OIL", "MUSTARD OIL", "ALKYL. DI
    strwb_treatment %in% c("ACEQUINOCYL", "BIFENTHRIN", "CARBARYL", "CHLORPYRIFOS", "CLOMA
    strwb_treatment %in% c("BIFENAZATE", "BOSCALID", "CAPTON", "CHLORANTRANILIPROLE", "CHL
    strwb_treatment %in% c("BUPROFEZIN", "CLOPYRALID MONO SALT", "CYFLUMETOFEN", "ETHEPHON
    strwb_treatment %in% c("CHLOROPICRIN", "PYRACLOSTROBIN", "PETROLEUM DISTILLATE") ~ "Fa
    strwb_treatment %in% c("DICHLOROPROPENE", "METHYL BROMIDE", "PEROXYACETIC ACID", "QUIN
    strwb_treatment %in% c("ACIBENZOLAR-S-METHYL", "AMMONIUM PELARGONATE", "AUREOBASIDIUM
    TRUE ~ "Unknown"
  ))
```

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