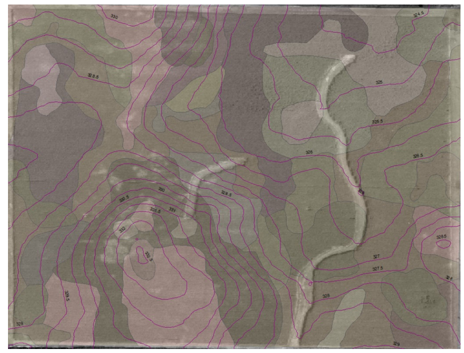
Variation in Agroecosystems

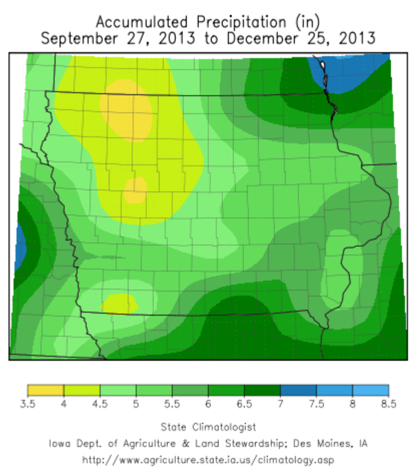
Spatial (edaphic):
- Fertility
- Drainage
- Structure
- Depth
- Slope
- Aspect
- Parent Materials



Soil mapping unit and elevation, ~ 40 acres, Sorenson Research Farm, Boone County, Iowa

Variation in Agroecosystems

Climatic (temporal):
- Temperature
- Precipitation
- Light
- Daylength
- Relative Humidity



Variability in Field-Plot Experiments

Early Papers

WHEELER, H. J. Some Desirable Precautions in Plat Experimentation.

THORNE, CHAS. E. The Interpretation of Field Experiments.

TAYLOR, F. W. The Size of Experiment Plots for Field Crops.

MORGAN, J. OSCAR. Some Experiments to Determine the Uniformity of Certain Plats for field Tests.

CORY, V. L. The Use of Row Plantings to Check Field Plats.

SMITH, LOUIE H. Plot Arrangement for Variety Experiments with Corn.

Agronomy Journal, Volume 1,1907-09.

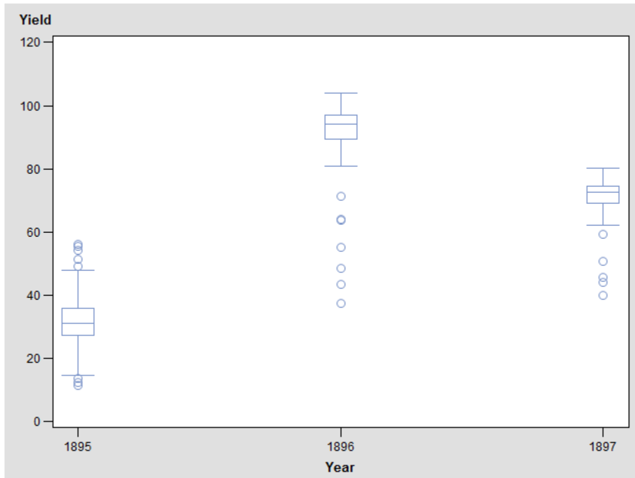
Variability in Field-Plot Experiments

Uniformity Trial
- 1/10 acre plots
- Plot area 6 x 20 plots (12 acres)
- Corn (shelled, bu/acre)
- No fertilizer
- Three years, same plots

	1895	**1896**	**1897**
Mean	31.7	91.6	71.4
SD	7.9	10.7	6.3
CV	25.1	11.7	8.8
Max	56.2	103.9	80.2
Min	11.4	37.5	40.0
d	44.8	66.4	40.2

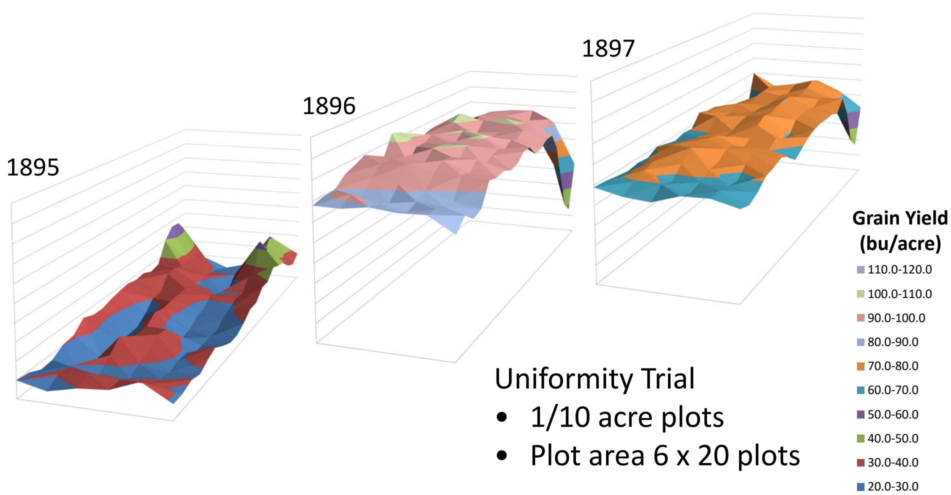
SMITH, LOUIE H.-Plot Arrangement for Variety Experiments with Corn. Agronomy Journal, 1909.

Variability in Field-Plot Experiments



SMITH, LOUIE H.-Plot Arrangement for Variety Experiments with Corn. Agronomy Journal, 1909.

Variability in Field-Plot Experiments



Uniformity Trial

- 1/10 acre plots
- Plot area 6 x 20 plots

SMITH, LOUIE H.-Plot Arrangement for Variety Experiments with Corn. Agronomy Journal, 1909.

Variability in Field-Plot Experiments

"The above results give us a conception of the unaccountable plot variations which we have to deal with in field tests…

The difficulty lies in the extremely complicated sets of factors involved. When we consider all of the physical, chemical, and biological processes of the soil, their inter-relations, and their dependence upon climatic conditions, the problem of their control becomes well nigh overwhelming."

SMITH, LOUIE H.-Plot Arrangement for Variety Experiments with Corn. Agronomy Journal, 1909.

Variability in Field-Plot Experiments

"The particular value that the writer has derived from this study is the strengthening of his conviction that the only dependence to be placed upon variety tests and other field experiments is from records involving the average of liberal numbers and extending over long periods of time."

SMITH, LOUIE H.-Plot Arrangement for Variety Experiments with Corn. Agronomy Journal, 1909.

Types of Experiments

Observational

- Data collected from a population (samples)
- Variables occur naturally
- No controls
- Descriptive in nature
- Tools:
    - Categorization
    - Correlation
    - Regression

Types of Experiments

Designed

- Treatments are applied to experimental units (plots)
- Data collected from experimental units (plots)
- Extraneous variation controlled
- Inferential - cause and effect
- Tools:
    - Analysis of variance
    - *t*-tests
    - Multiple comparison procedures
    - Regression / modeling

Characteristics of Designed Experiments

- Replication
- Randomization
- Design Control

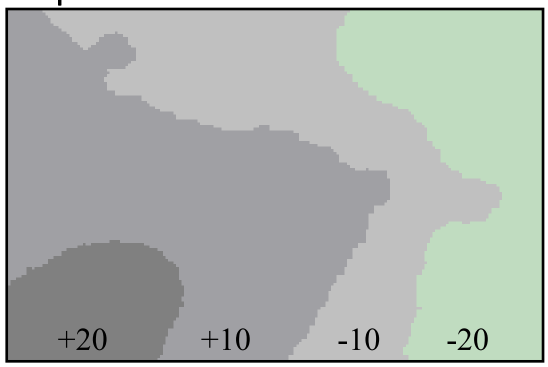
"Conventional statistics uses **local control**, **randomization**, and **replication** to estimate truth in the face of uncertainty. Local control incorporates systematic error into experimental design (e.g., through blocking, spatial experimental designs, or covariance analysis), randomization reduces the influence of systematic error, and replication is used to estimate the magnitude of the remaining unexplained error." Kimberly Garland-Campbell, 2018

Thought Experiment

- Forget what you know about statistics.
- You want to compare two plant varieties, Champ and Laser.
- You grow them side by side and one yields 8% better.
- Are you confident in that result?
- Why?

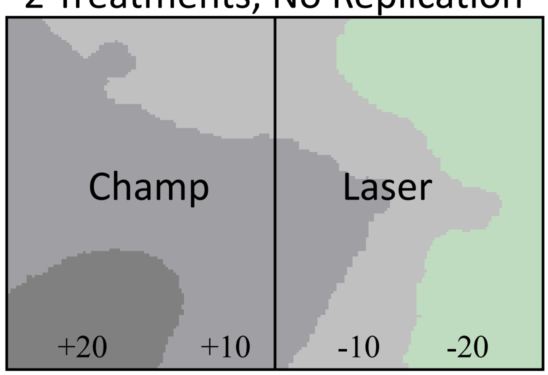
Spatial Variability

Spatial Effects on Corn Yield



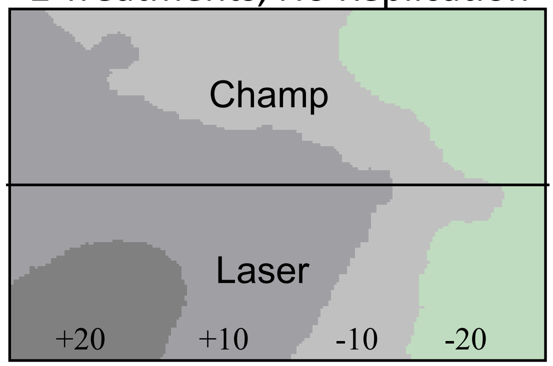
Spatial Variability

2 Treatments, No Replication



Spatial Variability

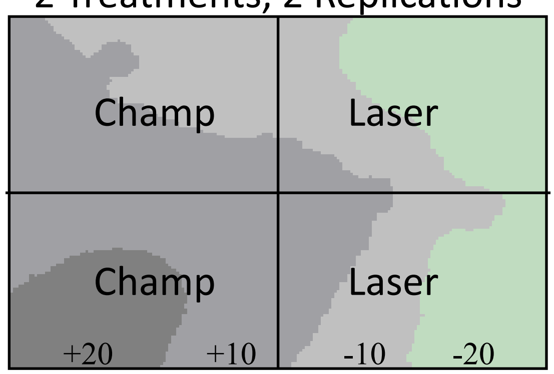
2 Treatments, No Replication



Spatial Variability

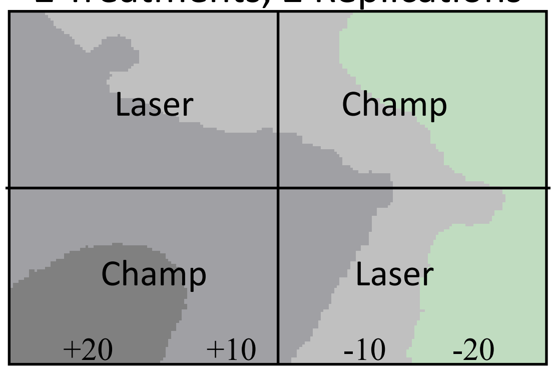
Replication

2 Treatments, 2 Replications



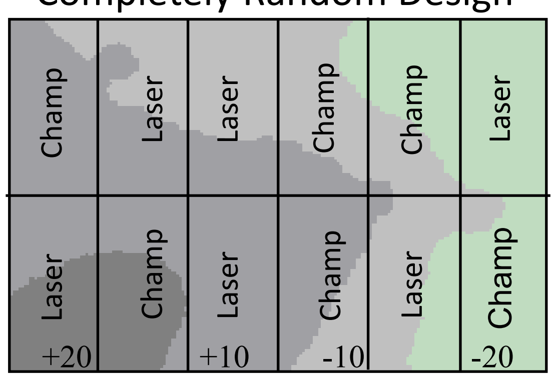
Spatial Variability
Randomization

2 Treatments, 2 Replications



Spatial Variability
Randomization

2 Treatments, 6 Replications
Completely Random Design

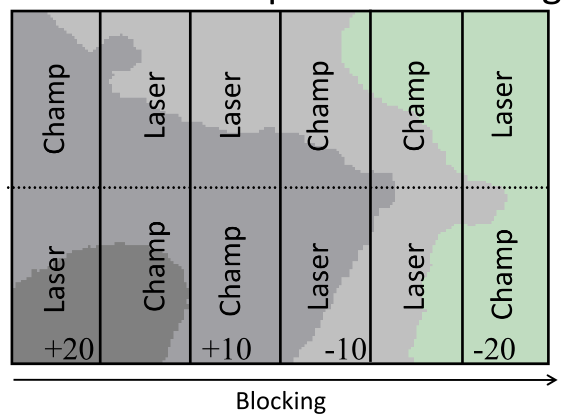


Spatial Variability

Design Control

2 Treatments, 6 Replications

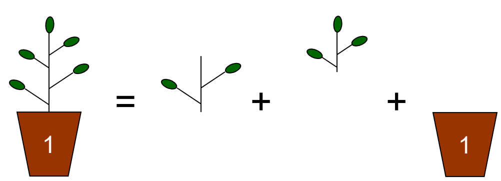
Randomized Complete Block Design



Statistical Models

What makes a statistical equation different from other equations?

$$Y_{ij} = \mu + T_i + \varepsilon_{(i)j}$$



Statistical Models

Example

$$Y_{ij} = \mu + T_i + \varepsilon_{(i)j}$$

- The Y_{ij} term left of the equals sign is the dependent variable.
- The terms to the right are independent variables.
- The subscripts refer to levels of the independent variables.
- The value of Y_{ij} is a linear sum of values of the independent variables for a given ij.

Statistical Models

Example

$$Y_{ij} = \mu + T_i + \varepsilon_{(i)j}$$

- The μ term is the overall or general mean of the experiment and has a constant value.
- The T_i term refers to the i^{th} level of the treatment applied to the experimental unit.
- The $\varepsilon_{(i)j}$ term is called the error term. It accounts for the residual difference between Y_{ij} and the sum of μ and T_i.

Statistical Models

Example

$$Y_{ij} = \mu + T_i + \varepsilon_{(i)j}$$

- The $\varepsilon_{(i)j}$ term is considered to be random and to conform to a normal distribution.
- The $\varepsilon_{(i)j}$ term accounts for the uncertainly associated with sampling from a population of items or individuals.
- It is the $\varepsilon_{(i)j}$ term that distinguishes a statistical model.
- It indicates that the model is correct on average with actual values lying somewhere within a defined distribution.

Statistical Precision

$$\text{Precision} = 1/\sigma_E^2$$

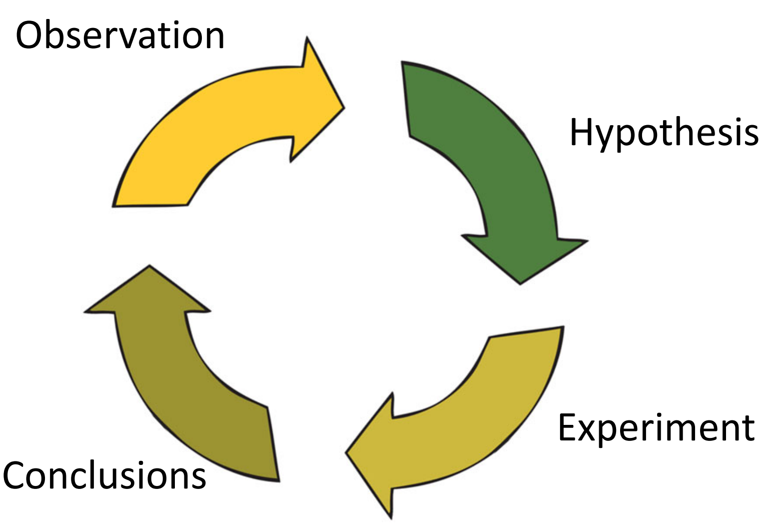
- The ability to detect treatment differences is proportional to the reciprocal of the experimental error
- Design controls are used to improve the precision of an experiment in detecting differences among treatments
- Design controls are therefore used to reduce experimental error
- They partition some of the variation away from error to other factors (e.g. blocks, covariates, etc.)
- These factors help to explain some of the observed variation among experimental units that otherwise would go unexplained

Science Defined

- "What is science? James Bryant Conant, who has a good claim to be the founder of modern history of science (he was Kuhn's mentor) defined it as '**a series of concepts or conceptual schemes (theories) arising out of experiment or observation and leading to new experiments and observations**'. **Science is thus an interactive process between theory on the one hand and observation (our old friend 'experience') on the other**."

David Wootton
The Invention of Science: A New History of the Scientific Revolution

The Scientific Method



Designing Experiments

1. Determine and understand the problem
2. Develop the hypotheses to be tested
3. Develop and conduct the experiment
   a. Specify variables to be measured
   b. Determine treatments to be applied
   c. Define inference space
   d. Select experimental units
   e. Develop experimental layout
   f. Write the linear additive model
   g. Specify the analysis
   h. Collect the data
   i. Analyze the data
4. Develop conclusions

Planning an Experiment
Asking a Good Question

- Learn from others – find out what is already known about your topic.
- Keep it simple – the more complex the question, the more complex the experiment.
- Consider potential impacts – who are you asking the question for?
- How important is answer – is it worth the time and expense?

Planning an Experiment
Formulating a Hypothesis

- What is a hypothesis?
  - A simple statement that captures what you are trying to discover.
- Examples
  - Are there yield differences among three new hybrids?
  - Does applying a nitrification inhibitor reduce nitrate leaching?
  - Is strip tillage as effective as no till in reducing soil erosion?
  - Does organic management improve nutritional value of soybeans?

Planning an Experiment
Formulating a Hypothesis

- Statistical hypothesis: statement about statistical parameters in your study
  - Null hypothesis usually states that no differences exist among treatment means.
  - Examples
    - The new hybrids of interest all have the same mean yield.
    - Nitrate leaching means are the same with and without a nitrification inhibitor.
    - Mean soil erosion is the same for strip tillage and no till.
    - Mean nutritional value of soybeans is the same for organic and conventional management.

Planning an Experiment
Error Control

- When you conduct an experiment, you want to be sure that you draw the right conclusions.
- Decide what levels of risk you are willing to accept from the outset.
- Stick to these during your analysis and interpretation.

Planning an Experiment
Type I Error

- Occurs when you find a statistically significant difference among treatment means when in fact, there really was none.
- Probability of making a type I error is termed the alpha level, and is denoted by the Greek letter α.
- Probability is expressed in decimal form.
  - Accepting a 5% chance of making a type I error is denoted as $\alpha = 0.05$.

Planning an Experiment
Selecting Treatments to Apply

- Generally follow logically from your hypothesis.
- Should include appropriate controls.
- Practical considerations:
  - Equipment
  - Cost
  - Precision
  - Time

Planning an Experiment
Selecting Variables to Measure

- Important responses to your treatment
- Specified or implied by your hypothesis
- Continuous on some meaningful scale.
- Practical considerations:
  - Ease of measurement
  - Accuracy and precision
  - Cost

Planning an Experiment
Other Measurements to Consider

- Variables other than your treatments that might affect your measured responses.
- May be important for interpreting your results.
- In some cases can be used to improve the sensitivity of your analysis.
- Examples
  - Location / Site-characteristics
  - Climatic conditions
  - Cultural practices

Planning an Experiment
Developing a Valid Experimental Design

- The design of an experiment refers to the way treatments are allocated to experimental units.
- An experimental unit is the individual entity to which treatments are applied.
- For field experiments, the experimental unit is generally a plot of land.
- The number of plots required for an experiment is equal to the number of treatments x the number of replications.
- The design dictates the appropriate analysis.

Planning an Experiment
Configuring and Laying Out Field Plots

- For statistical reasons, field plots (eus) should be as similar as possible.
- On-farm plots are usually relatively large for practical reasons.
- All plots in an experiment should be of the same size and dimensions.
- It is generally a good practice to include border rows between plots and is required when the treatment applied to an adjacent plot has the potential of influencing its neighbor.

Planning an Experiment
Controlling Other Factors

- List factors that may interfere with the treatments you have chosen for your study.
- Decide which factors you can control and which you can't.
- Controllable factors
  - Create strategies to ensure they are at levels than do not limit yields or quality.
- Uncontrollable factors
  - Measure their levels.

Defining Inference Space

- How far you can extrapolate your results is dictated by your design.
- Referred to as inference space.
- In general, inferences are limited to the factors included in your experiment.
- The results of an experiment conducted at one location in one growing season apply only to that growing environment.
- Inferences can be expanded by repeating the experiment over multiple environments (or other random factors).