Statistics: Used and Abused Tools of the Trade

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Statistics

• Tools for making decisions
  – “Is the untreated different than the treated?”
  – “What is the optimum fertilizer rate or seeding rate?”
  – “How much does delayed planting affect corn yields?”

We want to do this with some confidence about our final decision.
Confidence or Risk in Statistics
The basis for statistical decisions

Mean is often best forecast

<table>
<thead>
<tr>
<th>Year</th>
<th>farm A</th>
<th>farm B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td>$80</td>
<td>$5</td>
</tr>
<tr>
<td>Year 2</td>
<td>$200</td>
<td>$30</td>
</tr>
<tr>
<td>Year 3</td>
<td>$50</td>
<td>$20</td>
</tr>
<tr>
<td>Year 4</td>
<td>$270</td>
<td>$25</td>
</tr>
<tr>
<td>Year 5</td>
<td>$300</td>
<td>$30</td>
</tr>
</tbody>
</table>

Average: $20 $20

Five year average return per acre

How much confidence do you have in the $20 estimate?
When analyzing data

• The mean is a powerful measure/concept

• However, the mean does not convey all important and relevant information.

• We often also want to consider the variability in the data.
Measures of variability

- **Range** -- the difference between the largest reading and the smallest reading.

- **Standard deviation** -- a measurement of the total variability of the data. It is an average of deviations from the mean.

\[
s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n - 1}}
\]

- **Coefficient of variation (CV)** -- normalized measure of variability equal to standard deviation divided by the mean.
Standard deviation

- Same unit of measure as the original data
- Affected by extreme values, which tend to enlarge the standard deviation.
- Larger values for standard deviation indicate the data are more widely dispersed around the mean (i.e., more variable).
- Generally has the most meaning when data are normally distributed.
Probabilities and Statistics

- 2%: Definitely more than others
- 14%: Definitely less than others
- 34%: Mean Score
- 34%: Probably more than others
- 14%: Probably less than others
- 2%: Same as others

SD = Standard Deviation
Statistical Tests Often Used

• Mean Comparison
  – We have two or more products and we want to know if the response of one is different than the other

• Trend Analysis
  – We have a range of treatments of the same product and we want to know the optimum

• Spatial Analysis
  – Not going to talk about today
### Mean Comparisons

#### Analysis of Variance

**TABLE 4 continued. NORTHEAST KANSAS SPRINKLER IRRIGATION**

<table>
<thead>
<tr>
<th>BRAND</th>
<th>NAME</th>
<th>YIELD (bu/a)</th>
<th>PAVG (%)</th>
<th>TW (lb/bu)</th>
<th>MOIST (%)</th>
<th>DAYS (silk)</th>
<th>LDG (%)</th>
<th>100pp</th>
</tr>
</thead>
<tbody>
<tr>
<td>RENZE</td>
<td>1357YGPL/RR</td>
<td>188</td>
<td>99</td>
<td>57</td>
<td>17</td>
<td>64</td>
<td>0</td>
<td>24.9</td>
</tr>
<tr>
<td>RENZE</td>
<td>5347HX1/LL</td>
<td>192</td>
<td>101</td>
<td>56</td>
<td>18</td>
<td>66</td>
<td>2</td>
<td>25.9</td>
</tr>
<tr>
<td>RENZE</td>
<td>8386YGCB</td>
<td>186</td>
<td>98</td>
<td>55</td>
<td>19</td>
<td>67</td>
<td>3</td>
<td>24.4</td>
</tr>
<tr>
<td>RENZE</td>
<td>8428YGCB</td>
<td>177</td>
<td>93</td>
<td>56</td>
<td>18</td>
<td>65</td>
<td>1</td>
<td>25.9</td>
</tr>
<tr>
<td>RENZE</td>
<td>9328YGCB/RR</td>
<td>195</td>
<td>102</td>
<td>57</td>
<td>19</td>
<td>65</td>
<td>2</td>
<td>24.8</td>
</tr>
<tr>
<td>RENZE</td>
<td>9386YGCB/RR</td>
<td>178</td>
<td>93</td>
<td>57</td>
<td>18</td>
<td>65</td>
<td>0</td>
<td>25.2</td>
</tr>
<tr>
<td>TAYLOR</td>
<td>77640 RR</td>
<td>185</td>
<td>97</td>
<td>58</td>
<td>16</td>
<td>64</td>
<td>1</td>
<td>24.4</td>
</tr>
<tr>
<td>TAYLOR</td>
<td>930 RR/Bt</td>
<td>181</td>
<td>95</td>
<td>56</td>
<td>16</td>
<td>63</td>
<td>2</td>
<td>24.4</td>
</tr>
<tr>
<td>TRIUMPH</td>
<td>1608VT3</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>TRIUMPH</td>
<td>1866Bt</td>
<td>--</td>
<td>--</td>
<td>--</td>
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<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>TRIUMPH</td>
<td>1977CbRR</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>AVERAGE</td>
<td>190</td>
<td>190</td>
<td>56</td>
<td>18</td>
<td>65</td>
<td>2</td>
<td>25.0</td>
</tr>
<tr>
<td></td>
<td>CV (%)</td>
<td>9</td>
<td>9</td>
<td>2</td>
<td>9</td>
<td>2</td>
<td>--</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>LSD (.05)</td>
<td>24</td>
<td>14</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>2.3</td>
</tr>
</tbody>
</table>

* Seed treatments and hybrid traits located in Table 16.

** Yields in bold are in the top LSD group.

*** Unless two hybrids differ by more than the LSD, little confidence can be placed in one being superior.
LSDs and Alphas

- We see LSD\(_{(0.05)}\) and “significant at the alpha = 0.10” or “not statistically significant” in research reports.

- What does it mean?
- “Significant “ in statistics means “at the level of risk we are willing to accept, the evidence (sampled data) is sufficient to accept or discredit our H\(_0\)”
Null Hypothesis ($H_0$) and our “fears”

• Null hypothesis is typically
  – Hybrid A = Hybrid B

• Type I error is what our probabilities are focused on.
  – Type I is wrongly rejecting $H_0$
  – It happens when we conclude that Hyb A $\neq$ B and in reality they are the same.
**Analysis of Variance**

**Assertion of null hypothesis**

\( H_0 : \) All samples drawn from the same population  
\( (\mu_1 = \mu_2 = \mu_3) \)

**Assertion of alternate hypothesis**

\( H_A : \) At least one sample drawn from a different population  
\( (\mu_1 \neq \mu_2 \neq \mu_3) \)

**Case 1:**  
Small apparent difference between sample means  
Likely decision: do not reject \( H_0 \)

**Case 2:**  
Large apparent difference between sample means  
Likely decision: reject \( H_0 \)

*FIGURE 10.1*  
Null and Alternate Hypotheses in Analysis of Variance (ANOVA)  
*source: McGrew and Monroe (2000)*
### P value example

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Grain yield (Mg ha$^{-1}$)</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Water status</td>
<td>Water status</td>
</tr>
<tr>
<td></td>
<td>Adequate</td>
<td>4.52</td>
<td>5.32</td>
</tr>
<tr>
<td></td>
<td>Deficient</td>
<td>3.82</td>
<td>5.02</td>
</tr>
<tr>
<td></td>
<td>$P$ value</td>
<td>0.005</td>
<td>0.1</td>
</tr>
</tbody>
</table>

- **Human translation:**
  - In 2007, there is a 0.5% chance that these two are not different.
  - In 2008, there is a 10% chance that these two are not different.
Risk and Research

• Academics and researchers have been conditioned to be low risk takers because our results turn into recommendations in real life.

• We want to be VERY certain that narrow rows are better than wide rows before a farmer spends big $$$ to switch.

• However, in real life, 95% confidence (5% Pr > F) is not always likely necessary.
## Probabilities and Decisions?

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost ($/acre)</th>
<th>Benefit</th>
<th>Confidence Level</th>
<th>?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean Inoculant</td>
<td>$1.00</td>
<td>2 bushel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BT Corn (2001)</td>
<td>$5.00</td>
<td>0 bushel</td>
<td>75 - 80%</td>
<td></td>
</tr>
<tr>
<td>New Product “X”</td>
<td>$10.00</td>
<td>2 bushel</td>
<td>90 - 95%</td>
<td></td>
</tr>
<tr>
<td>Hyb A vs Hyb B</td>
<td>$0.00 (difference)</td>
<td>6 bushel</td>
<td>51%</td>
<td></td>
</tr>
</tbody>
</table>

Low cost and high return… do not need much confidence.

Did not find a big advantage to BT in two years tested, but infestation the next year could pay big.

New unproven product that costs $10.00/acre has a lot of risk.

Little risk here because you are going to plant something.
## Analysis of Variance Examples

### Plant Population (32,000 and 40,000 plants/acre)

<table>
<thead>
<tr>
<th></th>
<th>LY1</th>
<th>LY2</th>
<th>LY3</th>
<th>LY4</th>
<th>LY5</th>
<th>LY6</th>
<th>LY7</th>
<th>LY8</th>
<th>LY9</th>
<th>LY10</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>245</td>
<td>187</td>
<td>223</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>210</td>
<td>186</td>
</tr>
<tr>
<td>High</td>
<td>237</td>
<td>172</td>
<td>226</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>209</td>
<td>181</td>
</tr>
<tr>
<td></td>
<td>-8</td>
<td>-16</td>
<td>3</td>
<td>-11</td>
<td>9</td>
<td>-5</td>
<td>-8</td>
<td>-13</td>
<td>-1</td>
<td>-6</td>
<td></td>
</tr>
</tbody>
</table>

Bold numbers indicate years when means were different at the 10% level.

### Fertilizer

<table>
<thead>
<tr>
<th></th>
<th>LY1</th>
<th>LY2</th>
<th>LY3</th>
<th>LY4</th>
<th>LY5</th>
<th>LY6</th>
<th>LY7</th>
<th>LY8</th>
<th>LY9</th>
<th>LY10</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>230</td>
<td>176</td>
<td>221</td>
<td>230</td>
<td>195</td>
<td>165</td>
<td>122</td>
<td>195</td>
<td>98</td>
<td>211</td>
<td>184</td>
</tr>
<tr>
<td>High</td>
<td>252</td>
<td>183</td>
<td>228</td>
<td>248</td>
<td>208</td>
<td>175</td>
<td>137</td>
<td>196</td>
<td>105</td>
<td>208</td>
<td>194</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>7</td>
<td>8</td>
<td>18</td>
<td>13</td>
<td>10</td>
<td>15</td>
<td>1</td>
<td>7</td>
<td>-3</td>
<td>10</td>
</tr>
</tbody>
</table>

Bold numbers indicate years when means were different at the 10% level.

E. Nafziger: “Managing continuous corn for high yields” white paper
Comparing Treatments

• Often we get data from a large number of different studies and want to use them to give us a better picture of the situation.

• How do we compare all of these results?

• Simple comparisons are often vary useful.
Soybean Row Spacing Example

• When narrow row soybeans were being studied, a lot of results were being generated by universities.
• It seemed that some environments worked well, others did not?
• A difference plot can often be useful in determining environmental impacts.
Soybean Row Spacing Example

- Accumulate data
- Calculate the differences between the treatments
- Plot the data
  - Difference as the Y
  - Location average as the X.

<table>
<thead>
<tr>
<th>Location</th>
<th>Year</th>
<th>7.5 In</th>
<th>30 in</th>
<th>Difference</th>
<th>Loc Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manhattan</td>
<td>1997</td>
<td>10.6</td>
<td>13.2</td>
<td>-2.6</td>
<td>11.9</td>
</tr>
<tr>
<td>Ottawa</td>
<td>1998</td>
<td>19.4</td>
<td>19.7</td>
<td>-0.3</td>
<td>19.6</td>
</tr>
<tr>
<td>Lincoln</td>
<td>1998</td>
<td>25.5</td>
<td>24.3</td>
<td>1.2</td>
<td>24.9</td>
</tr>
<tr>
<td>SW IA</td>
<td>1999</td>
<td>31.8</td>
<td>29.8</td>
<td>2.0</td>
<td>30.8</td>
</tr>
<tr>
<td>Lincoln</td>
<td>1999</td>
<td>32.4</td>
<td>29.8</td>
<td>2.6</td>
<td>31.1</td>
</tr>
<tr>
<td>Mead</td>
<td>2000</td>
<td>34.0</td>
<td>31.5</td>
<td>2.5</td>
<td>32.8</td>
</tr>
<tr>
<td>Manhattan</td>
<td>2000</td>
<td>34.4</td>
<td>36.3</td>
<td>-1.9</td>
<td>35.4</td>
</tr>
<tr>
<td>Columbia</td>
<td>2000</td>
<td>38.1</td>
<td>37.2</td>
<td>0.9</td>
<td>37.7</td>
</tr>
<tr>
<td>MO</td>
<td>2000</td>
<td>40.9</td>
<td>37.8</td>
<td>3.1</td>
<td>39.4</td>
</tr>
<tr>
<td>VA</td>
<td>2001</td>
<td>45.0</td>
<td>40.8</td>
<td>4.2</td>
<td>42.9</td>
</tr>
<tr>
<td>Ark</td>
<td>2001</td>
<td>44.6</td>
<td>43.3</td>
<td>1.3</td>
<td>44.0</td>
</tr>
<tr>
<td>Manhattan</td>
<td>2001</td>
<td>48.0</td>
<td>44.8</td>
<td>3.2</td>
<td>46.4</td>
</tr>
<tr>
<td>Ottawa</td>
<td>2001</td>
<td>51.0</td>
<td>45.8</td>
<td>5.2</td>
<td>48.4</td>
</tr>
</tbody>
</table>
Soybean Row Spacing Example

-4
-3
-2
-1
0
1
2
3
4
5
6
7
0
10
20
30
40
50
60
-4
-3
-2
-1

Row Spacing Yield Difference (bu/acre)

Average Site Yield (bu/acre)

7.5 - 30 in
Overall yield response = 3.3 bu/acre
Positive yield response = 77%
Economically beneficial = 27%
Corn Fungicides in Kansas

Fungicide costs = $25/acre

$3/bu
$4/bu
$5/bu

Untreated Control

Treatment – Untreated Control (bu/a)

y = 0.161x - 32.336

R² = 0.324
t-Tests and Single Comparisons

- The Student t-Test is useful for comparing two treatments (Hyb A vs Hyb B).
- It is very simple
- It can be done in Excel.

<table>
<thead>
<tr>
<th>Replication</th>
<th>Hyb A</th>
<th>Hyb B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>159</td>
<td>158</td>
</tr>
<tr>
<td>2</td>
<td>161</td>
<td>155</td>
</tr>
<tr>
<td>3</td>
<td>159</td>
<td>156</td>
</tr>
<tr>
<td>4</td>
<td>165</td>
<td>153</td>
</tr>
</tbody>
</table>

Average: 161 | 156
St. Dev: 2.8 | 2.1

Prob > Z = 0.01
Regression Analysis

• “Line fitting” Analysis
• Is the most appropriate analysis method for rate related data such as planting date, planting rate, fertilizer rates.
• Easy to conduct
• Requires less knowledge of “statistics” as we are often looking for optimums.
## OverWorked and Mis-Used LSDs

<table>
<thead>
<tr>
<th>N Rate (lbs/acre)</th>
<th>Corn Yield (bu/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>99 c</td>
</tr>
<tr>
<td>40</td>
<td>151 b</td>
</tr>
<tr>
<td>80</td>
<td>192 a</td>
</tr>
<tr>
<td>120</td>
<td>204 a</td>
</tr>
<tr>
<td>160</td>
<td>207 a</td>
</tr>
</tbody>
</table>

Means followed by the same letter are not different at the 0.05 significance level.

So what is the optimum or recommended N amount based on these data? (Audience participation here...if awake)
Corn Yield and N

\[ y = 0.656x + 115.68 \]

\[ R^2 = 0.6472 \]
Corn Yield and N

Calculated optimum N rate = 138 lbs N/acre

\[ y = -0.0059x^2 + 1.6236x + 94.291 \]
\[ R^2 = 0.7664 \]
Calculated optimum N rate = 100 lbs N/acre
Corn Planting Depth and Yield

$$y = -0.0733x^2 + 0.3329x + 0.601$$

$$R^2 = 0.7987$$

Calculated optimum 2.25 in
Calculated Plateau = 2.00 in
Wheat - Date of Planting

\[ y = 100 + 0.5x \]

\[ y = 100 - 2.9x \]

Grain Yield (% of Maximum)

Days Relative to Optimum Planting Date
Data Sources

• Universities
  – Our job is to collect data, report it, AND give our opinion on what it means. Usually pretty conservative.

• Seed and Chemical Companies
  – Pioneer, Monsanto, and Syngenta (to name a few) have or are adding Crop Management personnel to collect production data. Ask for it.

• Collect your own...it is not difficult
Variable Rate Technology
<table>
<thead>
<tr>
<th>Rep 1</th>
<th>Rep 2</th>
<th>Rep 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid 1</td>
<td>Hybrid 1</td>
<td>Hybrid 1</td>
</tr>
<tr>
<td>Hybrid 2</td>
<td>Hybrid 2</td>
<td>Hybrid 2</td>
</tr>
<tr>
<td>Hybrid 3</td>
<td>Hybrid 3</td>
<td>Hybrid 3</td>
</tr>
</tbody>
</table>

Guidance Bars = Replication
Important Points

• Replication
  – Necessary for analysis and required to have confidence in results.
  – Often does not require a great deal of extra time if planned correctly.

• Yield Monitors and Yields
  – Use yield monitor to replace weigh wagon (measure grain mass).
  – Measure plot width and length manually.
  – Calculate yields and adjust for moisture as you normally would.
  – Do not use yield monitor calculated yields!! Errors could exist in plot length calculations by yield monitor because of incomplete header width and GPS error.
Summary

• Statistics are a tool that help you make informed decisions.
  – You must decide on the “risk” you are willing to take

• The key is to make sure that you are using real data to make decisions. “Plant health” does not increase price or decrease costs.
  – If you cannot measure it, you cannot manage it

• Analysis of Variance or Mean Separations work for treatments that have yes/no decisions
  – treated vs untreated; Hyb A vs Hyb B
Summary

• Regression or trend analysis is what you want to evaluate rate or response data
  – yield response to fertilizer or to plant population.

• Get as much data on a subject as you can prior to making a decision.
  – Informed vs uninformed decisions

• Do not be afraid to use statistics and if needed, ask for help. There are a lot of people who can help you
Mean Comparisons
Analysis of Variance

<table>
<thead>
<tr>
<th>Replication</th>
<th>Hyb A</th>
<th>Hyb B</th>
<th>Hyb A</th>
<th>Hyb B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>159</td>
<td>158</td>
<td>155</td>
<td>145</td>
</tr>
<tr>
<td>2</td>
<td>161</td>
<td>155</td>
<td>160</td>
<td>150</td>
</tr>
<tr>
<td>3</td>
<td>159</td>
<td>156</td>
<td>162</td>
<td>160</td>
</tr>
<tr>
<td>4</td>
<td>165</td>
<td>153</td>
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</tr>
<tr>
<td>Average</td>
<td>161</td>
<td>156</td>
<td>161</td>
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<td>2.1</td>
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<th>Source of Variation</th>
<th>Prob &gt; F</th>
<th>Prob &gt; F</th>
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<td>Rep</td>
<td>0.97</td>
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<td>Hybrid</td>
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Analysis of Variance

Between Group Variation

Within Group Variation

Total Variation
Analysis of Variance

“But it is 6 bu/a different”
Foliar Fungicides – Corn

Southwest Cont. Irr. Corn

Corn Yield (bu/a)

Stevens/Seward Co.  Haviland

- UTC
- QU14
- ST10
- ST12
- HL6
Foliar Fungicides – Corn

Northeast Rotated Corn

- Manhattan
- Rossville
- Scandia
- Meadowlark

Corn Yield (bu/a)

- UTC
- HL6
- HL9
- HL6-NP
- HL4.5-C
Soybean Fungicides
Manhattan 2006-2008 (multiple varieties)