Bookmark this page

# Learn By Doing Activity

## Scenario: Gosset's Seed Plot Data

The purpose of this activity is to give you guided practice in carrying out the paired t-test. Here is some background for the historically important data that we are going to work with in this activity.

### Background: Gosset's Seed Plot Data

William S. Gosset was employed by the Guinness brewing company of Dublin. Sample sizes available for experimentation in brewing were necessarily small, and new techniques for handling the resulting data were needed. Gosset consulted Karl Pearson (1857-1936) of University College in London, who told him that the current state of knowledge was unsatisfactory. Gosset undertook a course of study under Pearson and the outcome of his study was perhaps the most famous paper in statistical literature, "The Probable Error of a Mean" (1908), which introduced the t distribution.

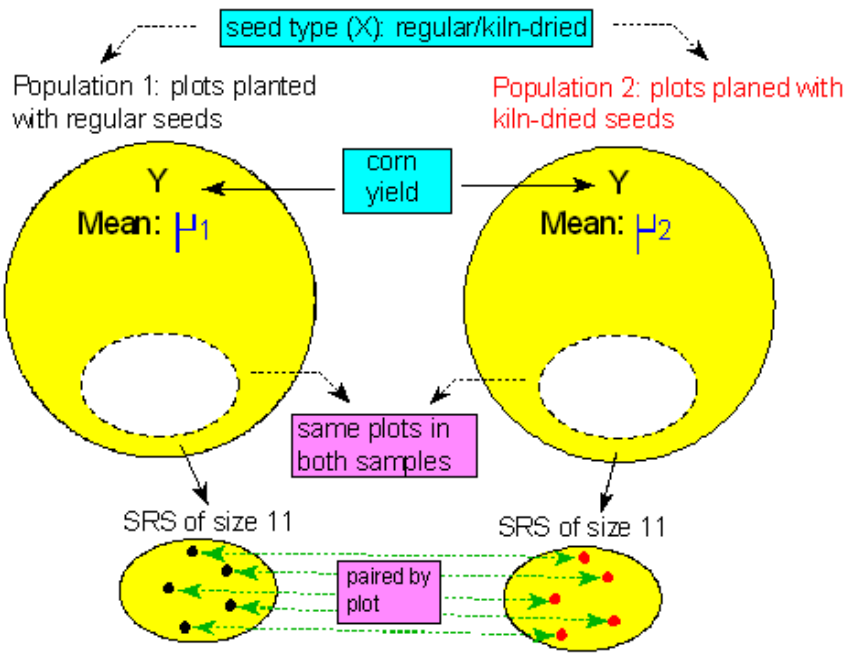
Since Gosset was contractually bound by Guinness, he published under a pseudonym, "Student," hence the t distribution is often referred to as Student's t distribution.

As an example to illustrate his analysis, Gosset reported in his paper on the results of seeding 11 different plots of land with two different types of seed: regular and kiln-dried. There is reason to believe that drying seeds before planting will increase plant yield. Since different plots of soil may be naturally more fertile, this confounding variable was eliminated by using the matched pairs design and planting both types of seed in all 11 plots.

The resulting data (corn yield in pounds per acre) are as follows:

| Plot | Regular seed | Kiln-dried seed |
|---|---|---|
| 1 | 1903 | 2009 |
| 2 | 1935 | 1915 |
| 3 | 1910 | 2011 |
| 4 | 2496 | 2463 |
| 5 | 2108 | 2180 |
| 6 | 1961 | 1925 |
| 7 | 2060 | 2122 |
| 8 | 1444 | 1482 |
| 9 | 1612 | 1542 |
| 10 | 1316 | 1443 |
| 11 | 1511 | 1535 |

We are going to use these data to test the hypothesis that kiln-dried seed yields more corn than regular seed. Here is a figure that summarizes this problem:




Because of the nature of the experimental design (matched pairs), we are testing the difference in yield.

| Plot | Regular seed | Kiln-dried seed | Difference |
|---|---|---|---|
| 1 | 1903 | 2009 | -106 |
| 2 | 1935 | 1915 | 20 |
| 3 | 1910 | 2011 | -101 |
| 4 | 2496 | 2463 | 33 |
| 5 | 2108 | 2180 | -72 |
| 6 | 1961 | 1925 | 36 |
| 7 | 2060 | 2122 | -62 |
| 8 | 1444 | 1482 | -38 |
| 9 | 1612 | 1542 | 70 |
| 10 | 1316 | 1443 | -127 |
| 11 | 1511 | 1535 | -24 |

Note that the differences were calculated: regular − kiln-dried.

## Learn By Doing (1/1 point)

State the appropriate hypotheses that are being tested here. Be sure to define the parameter that you are using.

**Your Answer:**

Ho: mu1 - mu2 = 0
Ha: mu1 - mu2 < 0

**Our Answer:**

Let μd be the mean of the yield difference "regular - kiln-dried" in a plot. Since we want to test the hypothesis that kiln-dried seed yields more corn than regular seed, the appropriate hypotheses are:
H0: μd = 0 Ha: μd < 0

Resubmit Reset

We created a histogram and boxplot of the differences data below.

## Learn By Doing (1/1 point)

Are the conditions that allow you to safely use the paired t-test satisfied?

**Your Answer:**

They don't seem to be, actually, because there were 11 plots of land (so like, 11 samples). The distribution also didn't look normal.

Edit: i guess it was actually okay!

**Our Answer:**

Let's check the conditions: (i) Even though the problem does not state it specifically, we can assume that Gosset "knew what he was doing" and the plots were chosen at random. (ii) The sample size is quite small (n = 11), so we need to make sure that the data (differences) do not display any extreme departure from the normality assumption. Typically we look at a histogram. Comment: some prefer to look at a boxplot of the data, since outliers are clearly marked, and skewness is apparent by the location of the middle line inside the box (which represents the location of the median relative to the quartiles). We recommend looking at the histogram (as we did previously) or at both graphs. Both graphs show us that the data does not display any departure from the normality assumption in the

form of extreme skewness and/or outliers. Note that 1) with such a small sample size of n = 11 we cannot really expect to see a normal shape in the histogram; so as long as we don't see anything that is extremely "non-normal," we're fine. 2) The boxplot shows us that no observation was classified as an outlier, and that there is no extreme skewness, since the median—the line inside the box—is roughly in the middle of the box). In summary, we can safely proceed with the paired t-test.

Resubmit Reset

## Learn By Doing (1/1 point)

Based on the visual displays, does it seem like there is some evidence in the data in favor of the alternative hypothesis? Explain.

**Your Answer:**

More of the differences looked negative -- this supports the alternative hypothesis.

**Our Answer:**
We notice that most of the differences (7 out of 11) are negative, indicating that in 7 of the 11 plots, the dry seeds produced more corn yield. This is evidence in favor of the alternative hypothesis, but the evidence is not overwhelming, so it is hard to say whether this is strong enough evidence to reject the null hypothesis in favor of the alternative.

Resubmit Reset

## Learn By Doing (1/1 point)

We conducted the paired t-test and found the t statistic to be -1.69 with a p-value of 0.0609. What conclusions would you draw?

**Your Answer:**

At a significance level of 0.05, our happening upon a t-statistic of -1.69 wouldn't have been statistically significant. So, there aren't enough evidence to reject Ho.

**Our Answer:**
The test statistic is -1.69 and the p-value is 0.061, indicating that there is a 6.1% chance of obtaining data like those observed (or even more extremely in favor of the alternative hypothesis) had there really been no difference between regular and kiln-dried seeds (as the null hypothesis claims). Even though the p-value is quite small, it is not small enough if we use a significance level (cut-off probability) of 0.05. This means that even though the data show some evidence against the null

hypothesis, it isn't quite strong enough to reject it. We therefore conclude that the data do not provide enough evidence that kiln-dried seeds yield more corn than regular seeds. Comment: While it is true that at the 0.05 significance level, our p-value is not small enough to reject Ho, it is "almost small enough." In other words, this is sort of a "borderline case" where personal interpretation and/or judgment is in order. You can stick to the 0.05 cut-off as we did above in our conclusion, but you might decide that 0.061 is small enough for you, and that the evidence that the data provide is strong enough for you to believe that indeed kiln-dried seeds yield more corn. This is the beauty of statistics ... there is no "black or white," and there is a lot of room for personal interpretation.

Resubmit Reset