Agricultural Statistics, Why Replication and Randomization are Important

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In CORN Newsletter 2005-39 (http://corn.osu.edu/story.php?issueID=117&layout=1&storyID=657), we had a lengthy discussion as to why replication and randomization are necessary for statistical analysis. From a theoretical perspective the article was important, but from an applied perspective why do we care? Today we will discuss the potential influence of factors other than those we are trying to evaluate on experimental outcomes, and how proper statistical design can ensure the conclusions reached are correct.

Replication

Assume you want to evaluate a fungicide treatment on your farm, so you split a field in two and apply the treatment to one half and leave the other half untreated. At the end of the year you harvest each of the two halves and observe a 3 bushel per acre increase in yield on the treated side. This 3 bushel per acre difference seems like a good deal, so you decide that next year all of your acres will be treated with this new fungicide.

Are you sure that the additional 3 bushels per acre was due to the application of the fungicide? Closer inspection of the field reveals that the half of the field that showed the yield response was dominated by a lighter texture soil that drained better than the other half of the field. Due to excessive moisture (this is not necessarily this past year) the half of the field with better drainage might be expected to perform better. With the field split in two, it is impossible to determine what factor contributed to the yield increase.

There are a multitude of other possible explanations for the yield increase: historical management differences, fertility level differences, insect pressure, disease pressure, natural variation in soil productivity, etc. Since we have no replication it is very difficult to reach a definite conclusion as to the cause of the yield increase. This is not to say that the 3 bushel per acre increase was not real, you just can not be positive that the yield difference was due to the treatment you applied.

Replication allows us to estimate the error associated with carrying out the experiment itself. Let’s revisit the fungicide experiment again. Assume you split the field into strips and established three strips that were treated with the fungicide and three that were not. We will look at two different scenarios based on the harvest information.

Scenario 1:
At harvest the yield levels of the three treated strips is 50, 59, and 50. The three untreated strips yielded 44, 57, and 49. The average yield levels for the treated and untreated strips are 53 and 50 bushels per acre, respectively. Statistical analysis (you will just have to trust my statistical skills) reveals that the probability of the fungicide treatment resulting in greater yield is approximately 43%. Stated another way, if you were to carryout the same experiment in this specific field environment, the fungicide treatment would result in a 3 bushel per acre yield increase 43 times out of 100. Notice the qualification in the previous sentence; these experimental results only pertain to this specific field environment (which may not be repeatable because field environment includes weather). This brings up another point, relying on a single year of information is probably not wise. Multiple years of information provides information over many different growing environments. Do not be fooled into rationalizing that the 3 bushel yield increase is a good bet because it may result in a yield increase 43 out of 100 times. Realize that the other 57 times the yield response will be negligible or possibly even detrimental.

Scenario 2:
At harvest the yield levels of the three treated strips is 54, 53, and 52. The three untreated strips yielded 50, 52, and 48. The average yield levels for the treated and untreated strips are 53 and 50 bushels per acre, respectively. Statistical analysis reveals that the probability of the fungicide treatment resulting in a 3 bushel per acre yield increase is approximately 92%. If you carried out the experiment 100 times under these field conditions, in 92 instances the fungicide treatment would be expected to result in a 3 bushel per acre yield increase. This is much more promising than scenario 1.

The only difference between the two scenarios is the variability in the data collected. The average for each treatment has not changed, but notice the spread in the data in scenario 1. Large variability in the data makes it much more difficult to identify treatment differences. In other words, some underlying source of variability exists that we cannot control or possibly even measure.

Randomization

While not stated explicitly in the Replication section, randomization is just as important as replication. Thinking about our initial experiment where the field was split in two. There was an underlying difference in soil productivity due to soil texture and drainage that could affect the experimental outcome by biasing the data. To properly conduct the experiment this variation should be accounted for in the experimental design. Even if you replicated both treatments (with and without fungicide) three times as you did in the Replication section, the conclusions you reach may not be correct if the fungicide treatment was always applied to the same half of the field. The data would be biased based on its location in the field.

In the next CORN Newsletter, we will discuss what LSD (Least Significant Difference) means and how it is used in statistical analysis.