Conducting On-Farm Research

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Research:

On-farm research empowers you to gather information under your management system in order to make informed decisions. Remember bad data leads to bad decisions.

Glossary of Terms:

Factor: An input class or group being studied. Nitrogen is a factor, seeding rates are a factor.

Treatment: The amount or rate of an input class or group applied. If nitrogen is a factor, two treatments for that factor may be 100 and 150 lbs N/acre. Similarly for seeding rates, 150 000 and 180 000 soybean seed/acre are treatments. Sometimes, treatments are called levels.

Replication: A research technique of repeating a treatment to reduce local influences. Often refers to how a set of treatments are grouped in a study.

Randomization: A research technique in which the order that treatments applied are determined by chance, not in a set manner that repeats.

Reps: a block of treatments that is repeated within a field to achieve replication of the treatments themselves.

Planning

Although it sounds like a cliché, planning is one of the most important steps in successful on-farm research. You are dealing with natural forces that sometimes can be unforgiving. Laying out your research project prior to going to the field can save a lot of time and energy. Also, if you have planned correctly, on the day you decide to implement the study (apply fertilizer, plant, etc.) you can focus on the job at hand, not developing the research protocol on the fly.

There are several steps to consider when planning a research study. The first obviously is deciding which factors you want to investigate and the treatments associated with it. The second is likely selecting a site that will accommodate the study.

Site Selection

Obviously flat, rectangular fields are ideal for conducting research in a traditional manner. However, most of us are not always blessed with such fields, and if you are not, do not feel too bad, often these fields are not as “perfect” as they seem.

Field size will often cause more headaches than field shape or slopes. Trying to fit 10 lbs of sugar into a 5 lb sack is not an easy task and putting three wheat seeding rate treatments, replicated three times into a field that will accommodate half that many treatments can be troublesome. Fields that are situated in a manner that allows you to easily apply treatments and identify the treatments to harvest are the best for on-farm research. These fields do not have to be flat and rectangular (Figure 1A) terraced fields can actually make treatment application easy if each terrace is split in half with a treatment on each half and replications are placed up or down the slope. (Figure 1B). Reps (replication blocks) should be positioned so that the entire block is on similar soil types or slopes so as to minimize the impact of these conditions.

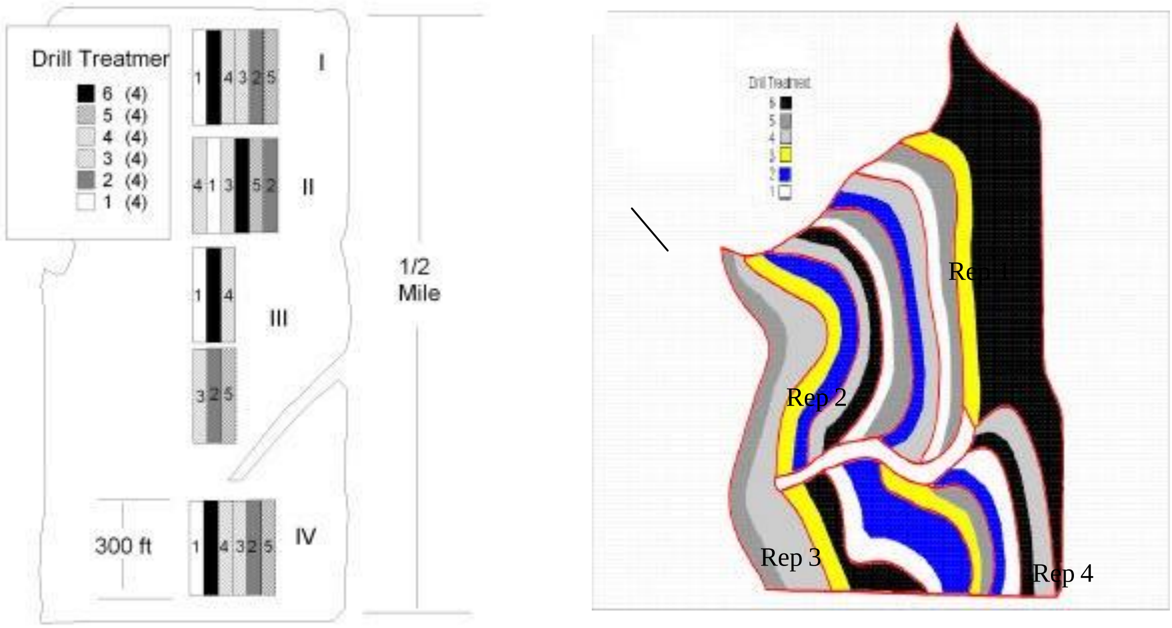

Figure 1. Two methods of implementing treatments. On the left, a traditional layout in a flat field. On the right, treatment implementation in terraced ground in which each terrace was split with each half containing a different treatment. Solid, heavy lines represent terraces.

Treatment Selection

Keep it simple, especially at first. Often a new researcher’s initial desire is to investigate everything. A study that includes planting dates, nitrogen rates, previous crop and seeding rates in wheat will require approximately 60 acres and several days to layout and implement, if you remembered to plant the previous crops the year before in a useful manner. For the novice on-farm researchers, it is often recommended to start with one factor and less than 10 treatments. Three to six treatments would be better. Treatment levels or rates used in experiments should represent a range the helps you make a decision. There are two types of factors in crop production research: discrete and continuous. Discrete factors include treatments that are similar or being compared in a “head-to-head” manner. A comparison between fertilizer A and B is an example of a discrete factor. Comparisons of such things as different herbicides, seed applied insecticides, soybean inoculants are all discrete factors. Continuous factors are those that are rate dependent. Seeding rate and fertilizer rate treatments are the best examples of continuous factors. In these cases, we are applying the same input, just at different rates. Understanding whether you are examining a discrete or continuous factor is important when designing experiments and selecting treatment levels.

For discrete factors, the rate is not often important, it is typically the rate recommended by the manufacturer. Investigating the use of soybean inoculants (with and without inoculant) may be considered a discrete or continuous factor, but in many cases, it is easier to just consider them a discrete factor. Replication and randomization are the keys to successful testing of discrete factors. Taking short cuts with may lead to misleading results or no results at all.

When researching continuous factors, selecting the rates to use and the number of treatments is a very important decision. In most cases, we start off with the premise that a continuous variable can be described with a response function (Figure 2). This implies that as we increase or decrease the amount of any continuous factor, yields or whatever is being measured will also increase or decrease until some optimum level is reached. The goal of field research is to try and identify that optimum level as that will indicate the rate at which the system is at an optimum.

Treatment levels should be chosen to try and identify where you currently are on that response curve and the shape of that curve.

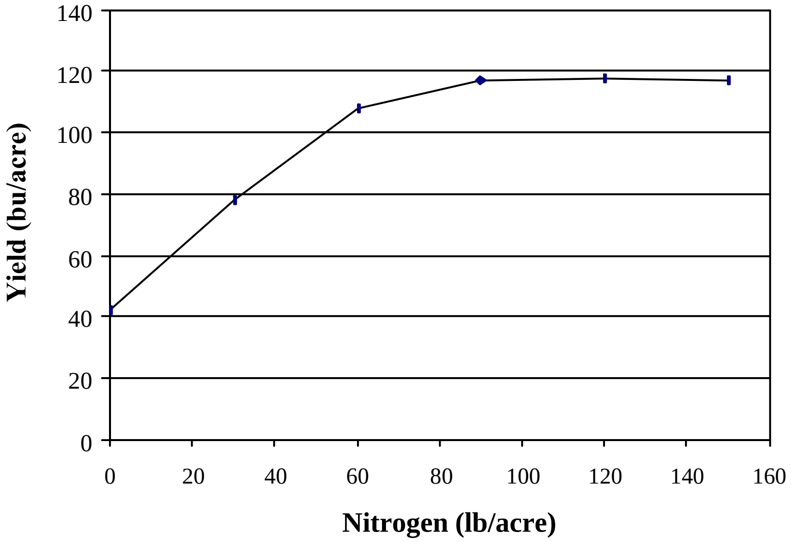

Figure 2. Yield respone to increased nitrogen rates.

For example, if you think that you may be planting your soybeans too thick, select three to five seeding rates with your current seeding rate as a reference. There are two approaches to selecting treatment rates in this case. The first is to bracket your current seeding rate by selecting treatment levels above and below your seeding rate. If you are only using three treatments, then one above, one below and your current seeding rate would be the treatment levels. If you want to have four treatments, in this case one above your current seeding rate to determine if you actually need to increase your seeding rate, your current seeding rate and two rates below your current rate since this is the direction you believe you can move. If you choose five treatments, two above and two below your current seeding rate and your current seeding rate might be your treatments. People are often reluctant to add the treatments in the opposite direction they think they should be moving (higher seeding rates in this example). However, these treatments provide two important bits of information. The first is that it will help describe the response function.

Secondly, it is entirely possible that you misjudged where your current rate is on the response curve and the correct decision is to change your input levels the opposite direction than you originally believed. In this example, to increase your soybean seeding rates rather than lower them.

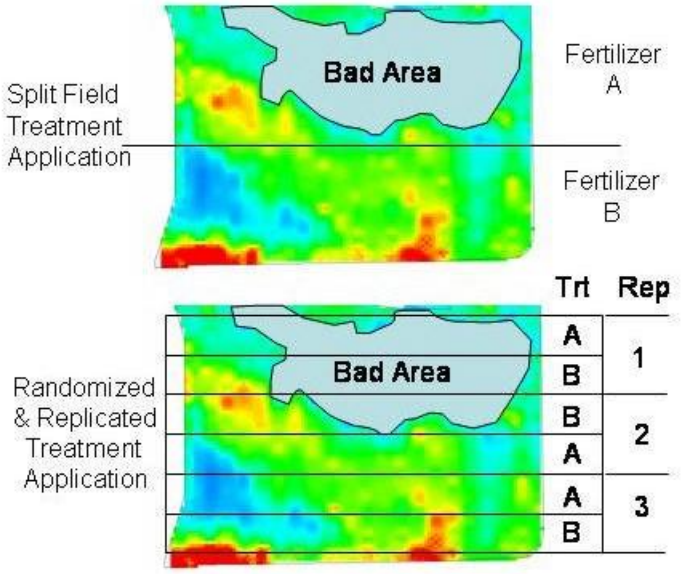

Figure 3. Example of a how splitting a field with a bad area (top) can result in one treatment being at a disadvantage. The lower example shows how replication can help remove the bias that a bad area in the field can have on treatment performance.

Select treatment levels that are far enough apart to be useful. The first thing to consider when selecting treatment levels, may be whether you can actually apply them. Often this problem occurs when small differences between treatments are selected. For example, having 5 nitrogen treatments 10 lbs/acre of N apart may be difficult to actually apply, even if you believe you can. Also, this level of difference is probably not economically significant to begin with. A good rule of thumb is to start with treatments that are approximately 15% different than your current rate. If your current soybean seeding rate is 180,000 seed/acre, consider treatments of 150,000 (15% less than 180,000), 120,000 and 90,000 seed/acre. If space is limiting when designing a study with continuous variables, it may be desirable to trade treatment levels for replications. Replication

Why replicate treatments across a field, lets just split the field in half to test Super Fertilizer A and Super Fertilizer B? There are two reasons to replicate treatments across a field. The first is that if fertilizer A out yields fertilizer B by 16 bushels, how sure are we that this is true? If fertilizer A out yields fertilizer B by 5 bushel one time and 20 bushel the next time, how sure are we that the difference is true. However, if fertilizer A out yields fertilizer B by 5, 16, and 20 bushels to the acre we have more confidence in the decision that fertilizer A is better than fertilizer B. In fact, we can calculate several statistics (standard deviation, Variance, or coefficient of variation) to describe how much confidence we have in the answer. The second reason to replicate is that not every field is the same. If fertilizer A was applied to the side of the field with good soil and fertilizer B was applied to the side of the field with the eroded side slope, was it the fertilizer or the soil that caused the yield difference. Replication will allow each fertilizer to be applied to similar soil/growing conditions. Replication can also help us in dealing with changes in soil types/properties. If we have both fertilizer A and B on the good soil, both treatments on the eroded side slope, and both treatments in the sandy area, then the nitrogen differences, not the soils differences can be observed. Two replications of wheat seeding rates on the half of the field that was corn and two replications of wheat seeding rates on the half of the field that was soybeans will help us "remove" or account for the influences of the different previous crops (Figure 3).

Replication should not be sacrificed if at all possible, with one exception that will be addressed later. If necessary, test fewer factors or treatments to accommodate three replications. Four replications are ideal as it allows one to be lost to natural or man-made causes without severe consequences to the analysis.

Randomization

Why "mix-up" the treatments, let's just apply the 50 then the 100 then the 150 lbs N/acre and repeat it three times across the field in that same order? Randomization removes any bias that we may unknowingly place on a set of treatments. Is it possible that the treatment next to the low nitrogen rate receives more sunlight because the plants in the low nitrogen treatment are shorter? If the medium nitrogen rate is always next to the low, then the medium nitrogen rate may have higher yields, not because it is the best nitrogen rate, but because of artificial conditions we created. Remember bad data leads to bad decisions.

Randomization also removes the tendency to have one treatment always in the best spot. If treatments are assigned by chance, or randomly, then every treatment has the same chance of being applied on the good soil as well as the same chance of being applied on the bad soil. The hope is that these placements occur evenly for each treatment.

Data Analysis

Data analysis is a very important step in any research study. Using statistics often sounds scary to many people, but are necessary tools for making decisions about and from the data that is collected from a research study.

Statistical analysis determines the probabilities of treatments being different based on just a few data points. For example, if we applied fertilizer A and fertilizer B side by side in the same field for 20 years, we would have a pretty good idea if one fertilizer was better than the other because we have many observations. However, we would not have a lot of confidence after just the first year or two, especially if the results were drastically different each year. Replication and statistics allow us to calculate the probability that one year's worth of data (if we have some replication) is similar to what we believe would happen if we ran the experiment many times (i.e. 100 times).

There are several key statistics that are often used just to describe a data set. They include the following:

Mean – the average of a set of numbers.

Variance – describes how spread out a dataset is with respect to the mean of the dataset. It is actually computed by comparing each number in a dataset to the mean of a dataset. A dataset containing 2, 2, 3 and 5 will have a mean of 3 and a variance of 2. A data set containing 1, 2, 4, and 5 will have a mean of 3 but a variance of 3.3.

Standard deviation – provides similar information as the variance, in fact it is calculated by taking the square root of the variance. The standard deviation is more commonly used.
Coefficient of Variation – is a term that describes the overall variability of a dataset. Coefficient of variation (C.V.) is often used because it normalizes data to the mean since it is calculated by dividing the variance of a dataset by the mean of a dataset. As a result it is expressed as a percentage and the units cancel out. For example if I am looking at grain yields for two treatments, the mean could be 100 bu/acre with a variance of 38.8 bu/acre. If I am measuring the distance that a guidance system is from pass to pass, I might have a mean error in the system of 12 inches with a variance of 6.3 inches. Which dataset had more variability? If we divide each variance by the mean, the units cancel and we have the C.V. which incidentally is 38% for the yield data and 49% for the guidance data.

Calculating a mean for each treatment and a mean, standard deviation and C.V. for the entire study should be the first steps in analyzing data. Obviously, comparing differences between the treatment means would be the first step in deciding if the treatments had an impact on yield. Be careful not to read something into small differences that truly do not exist. It is true that two bu/acre increase in soybean yield may be worth $12/acre, but if treatment A is only two bu/acre better than treatment B in 60 bu/acre irrigated soybeans, is that two bushel increase reliable or real? A good rule of thumb to use is that if the differences between two treatment means are not greater than 10% of the overall study mean, then it is likely that this difference is not truly meaningful. For in-depth analysis, an analysis of variance or regression analysis should be performed. These two procedures are discussed later in this section.

A large standard deviation indicates that there was a lot of variability among the treatments in the study. The key is to decide if it was caused by the treatments you applied or variations in the field. If the standard deviation is high and the treatment means are fairly close together, it would suggest that field variability may be the problem. If one treatment is much greater than the others, this can cause high standard deviations and C.V.s. A C.V. below 10% is considered good for small plot research, one below 15% would be considered good for large plot research.

The real value in analyzing data is determining if treatments are different. That is the primary reason for conducting research. Two techniques are often used to determine if treatments are different and which technique to use will depend on the type of data and intended uses of the results. These two techniques are called analysis of variance and regression analysis. Analysis of variance is most suited for treatments that are direct comparisons and not rate related. Analysis of variance is useful when comparing two soybean inoculants to each other as well as an untreated control. As is implied by the name, the variability between the variance within each treatment is compared to the overall variance of the entire dataset.

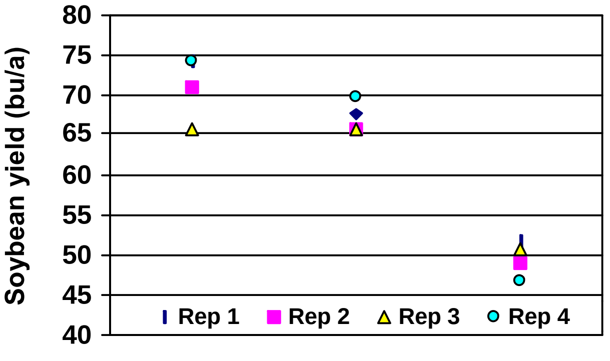

Figure 4. Example of treatment variability across replications and treatments.

In the example below (Figure 4), it is obvious that under irrigation, not using soybean inoculant in field that had not been in soybean for the past 8 years reduced yields compared to the two inoculant treatments. However, the next decision to be made, regards the difference between the two inoculants. Inoculant 1 has a mean yield of 71.2 bu/acre and inoculant 2 has a mean yield of 67.2 bu/acre, at $6.00 per bushel, this is a sizable financial difference. However, when the data are analyzed, the data for inoculant 2 are quite variable compared to inoculant 1 and the LSD, the statistic used to determine if two treatments are different, is equal to 4.2 bu/acre. This indicates that when two treatments have means farther apart than 4.2 bu/acre, we have enough confidence to say that the treatments are truly different. In the case illustrated above, the two treatments are not more than 4.2 bu/acre apart, so we conclude that inoculant 1 was as good as inoculant 2.

The steps associated with conducting an analysis of variance are not complicated. However, the steps to complete it are beyond the scope of this paper. If you wish to perform an analysis of variance on your own data, it can be accomplished in a spreadsheet and several free software package exist that can handle simple datasets. Any statistics book will have the mathematical steps required to conduct an analysis of variance and how to make decisions from it.

Regression Analysis

Regression Analysis is often referred to as curve fitting or trend analysis. As you would suspect from the name, regression analysis is used for examining trends in continuous data such as fertilizer or seeding rates. Regression analysis can also be used to determine if treatments effects exist like in the analysis of variance analysis, but it is often more difficult to separate individual treatment effects such as when inoculant 1 and 2 were compared directly.

Regression analyses are relatively easy to conduct in spreadsheets like Microsoft Excel, Lotus or Quatro. In most of these software packages, it is an option associated with creating graphs or built in functions. Regression analysis results indicate the rate of change in some measured value, as some controlled value changes. In the example here, the number of skips in a corn stand is expressed against planter speed. The objective of the research was to determine how increasing planter speed affected plant stand uniformity and final yields. The regression results indicate that each time the planter speed increased one mile per hour, we can expect about 1.6 skips for every 100 plants we examine. We know this by examining the equation in figure 5. The slope of the line through the data is 1.6.

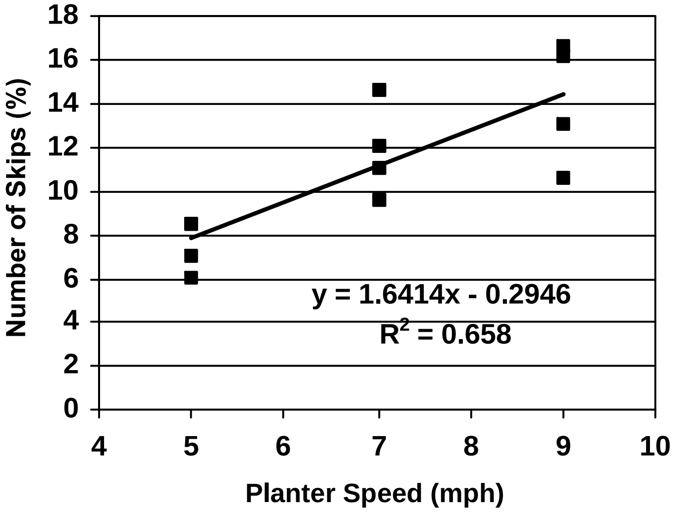

Figure 5. Impact of planter speed on skip appearance in corn.

A more common use for regression analysis is finding optimal rates for continuous factors such as fertilizer, seed or water. If we refer back to figure 3, it is easy to notice that yields no longer increase after nitrogen rates exceed approximately 90 lbs N/acre. Finding this optimal amount of nitrogen can be useful since we know that if we apply less than 90 lbs N/acre, we will potentially give up yield and if we apply more than 90 lbs N/acre, we are over applying fertilizer. Once these responses are developed, the economically optimal N rate can be calculated if crop value and nitrogen fertilizer prices are known. As mentioned earlier, when developing response functions, through regression analysis, fewer replications and more treatments may be desirable (Table 1). In many cases, during the analysis, outlying or bad data points can easily be identified and either accounted for or removed from the data set. In other words, two replications of five treatments may be more useful in answering the question at hand than three replications of three treatments. It is also possible to have incomplete treatment levels within replications. The table below illustrates how this may work.

Table 1. Example of how treatments may be distributed in a field that can accommodate 9 total treatments using a balanced and unbalanced design.

Soybean Seeding Treatment	Balance Design	Unbalanced Design
seed/acre	reps that treatments are included in	
210,000	1, 2, & 3	1 & 2
180,000	1, 2, & 3	1 & 2
150,000	1, 2, & 3	1 & 2
120,000		1 & 2
90,000		1

Technology and Field Research

Site specific technology has fueled on farm research during the past decade as time consuming tasks at planting and harvest can now be eliminated or drastically reduced. There are several tools that can make on-farm research less stressful to conduct as they do reduce the amount of time needed to implement, harvest and analyze a study.

Geographic Information Systems or similar software make field selection, study design and statistical analysis much easier then in the past. The ability to measure a field prior to leaving the house or office to determine if the field is large enough to accommodate the number of treatments and replications is extremely useful. It sure beats handling a 100 foot tape measure in the wind to determine if you have the 600 feet needed for a study. The ability to display recorded treatment data after planting is a valuable record keeping system. Another very important role of GIS software is the ability to manage yield monitor data and extract treatment yields by highlighting the areas where the treatments were applied (Figure 6).

GPS itself is one of the most important technologies in conducting on farm research. The ability to determine and record position is a fundamental, yet transparent, component of yield monitoring and guidance systems. More recently, the ability to record as applied maps has reduced the amount of time and record keeping needed when implementing research treatments. The ability to record spatial field notes has improved the quality of data collected from on-farm research studies.

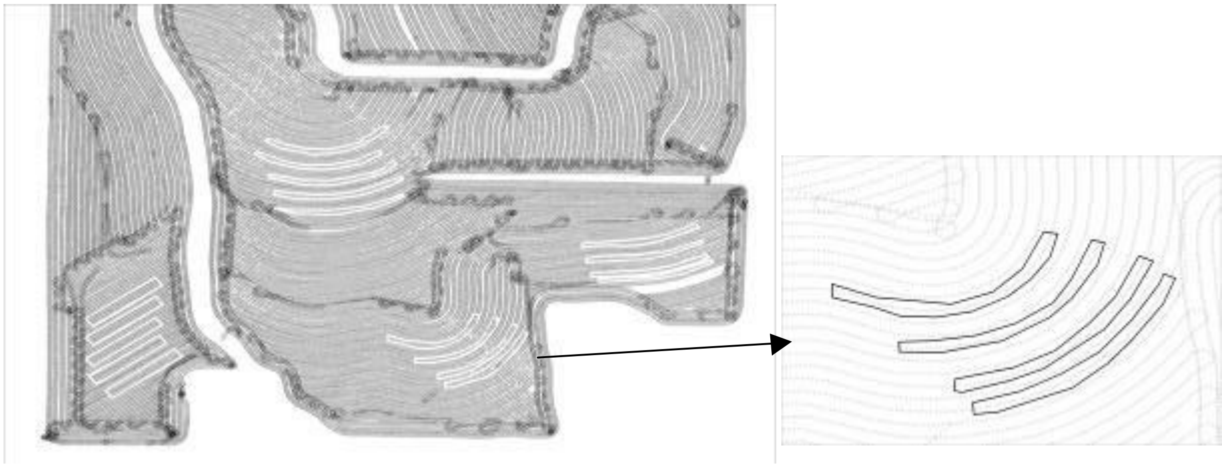

Figure 6. Soybean treatments (outlined in white) superimposed on yield monitor data (black diamonds) on left. Yield monitor data highlighted for extraction to determine treatment means for a replication within this field on right.

Guidance systems have proven useful when applying treatments that require adjustments to application equipment between treatments. With most guidance systems, you can count passes from an A-B line. Assigning pass numbers to each treatment within each replication makes it easy to apply three replications of the same 90 lb/acre nitrogen rate before switching to the next nitrogen rate. This approach was used in 1999 south of Lawrence, KS to plant a soybean row spacing and seeding rate study. Row spacing treatments were applied with two different pieces of equipment (drill and split row planter) with each requiring manual adjustments to change seeding rates. A guidance system was used to apply all three reps of one treatment when the equipment was set for that treatment (Figure 7).

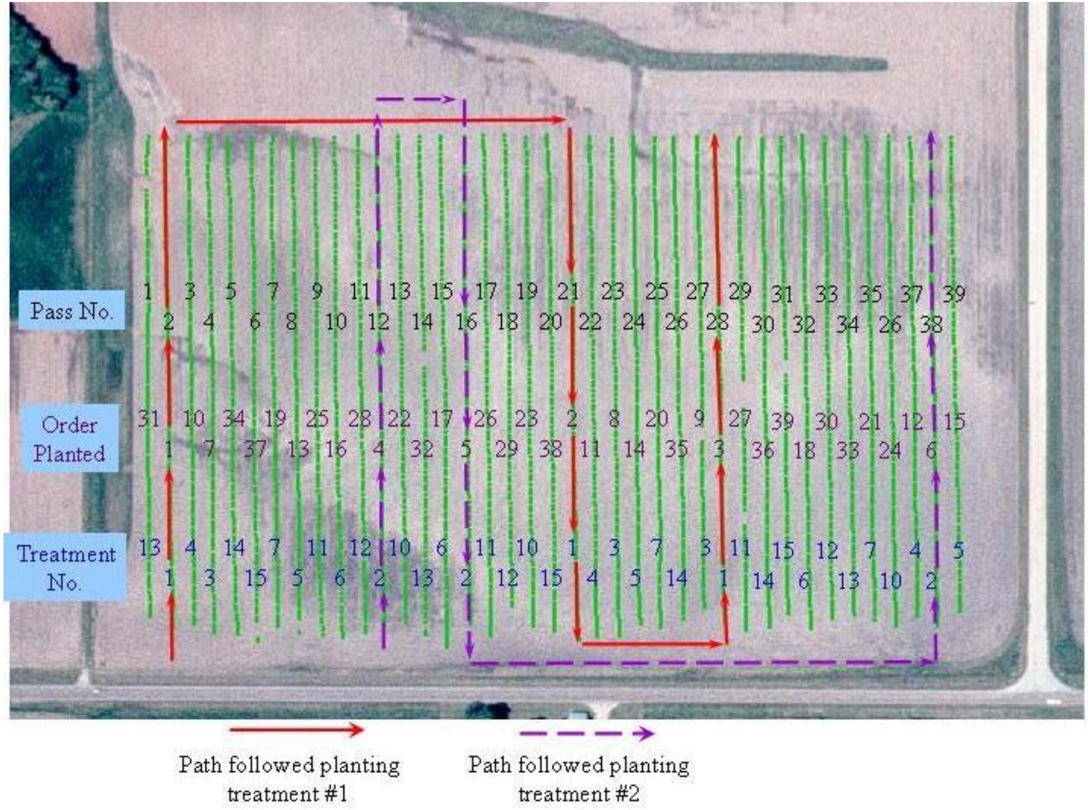

Figure 7. Illustration of how a guidance system was used to apply three replications of thirteen treatments in a field south of Lawrence. KS in 1999.

Yield Monitors are the site specific technology that is responsible for interest in on-farm research. Producers have always been interested in how fertilizers, hybrids and other inputs affect yields on their own farms, but the use of weigh wagons hampered these interests as they were too time consuming. Yield monitors enabled producers to get the same numbers as a weigh wagon provided, without stopping the combine. Using yield monitors to measure treatment yields has been a controversial topic in the past, however, research conducted at Kansas State University and other institutions have shown that when used properly, yield monitors are as accurate as weigh wagons. Several important precautions must be followed in order to achieve this level of accuracy. The first is to make certain that the yield monitoring system is calibrated for the grain and harvest conditions. Second is to make certain that treatments are large enough so that accurate measurements can be made with the yield monitor. Treatment width is not critical, as long as it is wide enough so that an even header width and adequate grain flow past the mass flow sensor can be achieved. Treatment length is important, because most erroneous data from a yield monitor occurs as the combine is filling up and cleaning out at the ends of a harvest path. A minimum of 300 feet is recommended for plot lengths so that accurate data can be collected at high grain flow rates for each treatment. Removing data 50 feet from the starting and stopping points is recommended to eliminate the erroneous data. Be certain to harvest the strips without stopping or sudden changes in ground speed to improve data quality.

For the greatest accuracy, consider using the yield monitor as a weigh wagon. Impact plates in a yield monitoring system measure mass flow (grain weight). Yield for a given data point or area is calculated based on this flow rate and ground speed and header width. Errors in the latter two may induce errors in estimating yields. If the area being harvest is measured by hand or in a GIS and the header width is constant, then errors in calculating the area harvested can be reduced.

Summary

Successful on-farm research is possible with careful planning, record keeping and attention to detail. Site and treatment selection are essential first steps. Remember to keep trials simple at first until you become comfortable implementing, harvesting and analyzing on-farm trials. Replication and randomization should not be avoided and if are not possible, it may be best not to conduct the research, remember, bad data results in bad decisions. Data analysis can be as simple as inspecting treatment means or as complex as completing an analysis of variance or regression analysis.