Guide to On-Farm

REPLICATED STRIP TRIALS

On-Farm Network®

Publication of the Iowa Soybean Association

ON-FARM NETWORK®

The Iowa Soybean Association (ISA) On-Farm Network® was formed in 2000 to conduct field trials for comparing various nitrogen and manure management practices. Since then, the focus has expanded to study many corn and soybean topics including guided stalk sampling, soil testing and disease scouting in addition to replicated strip trials.

Early On-Farm Network soybean research used replicated strip trials to test foliar fertilizers, fungicides,

tillage practices and seed treatments among others products and practices.

The On-Farm Network works closely with the other ISA research teams, university researchers, industry and government organizations on a wide variety of topics aligned with issues farmers care about, including pest and nutrient management, planting populations and cover crops among many others. These relationships allow the On-Farm Network to provide data as a trusted third-party source to enhance farmers' management decisions in efforts to improve profitability and environmental stewardship.

Chapter 1:

THE NEED FOR ON-FARM RESEARCH

Farmers have tested products and practices in their own fields for years. While advancements in technology have made it easier than ever to collect data, some farmers haven't yet taken the opportunity to conduct their own scientifically sound research. Using precision agricultural tools, many farmers can get first-hand experience evaluating practices and technologies, learning what works and what doesn't, without investing their entire operation.

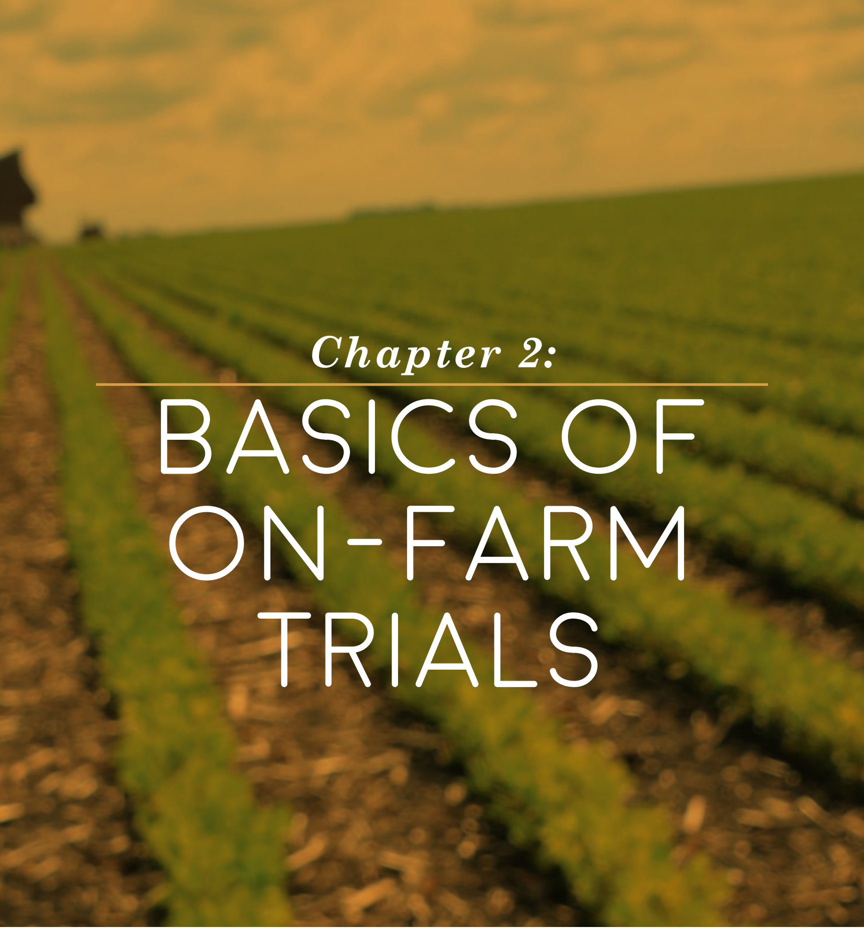
Farmers can better manage their fields with data collected on their farms. Results from on-farm research compiled across multiple sites and years can improve understanding of how current management practices, products, weather and soil variability affect yield and profitability. Information also can be aggregated to further benefit farmers within a region in making

management decisions. Localized networks allow farmers to collect credible, multi-state data to improve management practices.

This book provides a practical guide for farmers, agronomist, researchers, consultants and others interested in on-farm research. Its contents include:

- **How to set up replicated strip trials**
- **How to collect and summarize data**
- **Methods on ways to analyze data**

It is not intended to cover all aspects or possible scenarios of on-farm research. This book also may help other audiences, such as governmental agencies, non-agricultural organizations and other stakeholders, understand the process farmers go through to test products and practices on their operation.



Chapter 2: BASICS OF ON-FARM TRIALS

ON-FARM REPLICATED STRIP TRIALS

On-farm trials are usually conducted by farmers with the help of local agronomists, consultants or their regional On-Farm Network field research specialist. Farmers usually use their own planter, application equipment, tillage implements or sprayers to establish the trials and use combines equipped with GPS and yield monitors to collect spatial data.

On-farm replicated strip trials are field experiments that, when well executed, can be used to draw statistically valid cause and effect relationships between factors measured across and within fields.

TRIALS WITH THE ON-FARM NETWORK

When setting up a trial with the On-Farm Network, the participating farmer is expected to:

- Implement the trial
- Provide spatial and management data for trial fields

The On-Farm Network will:

- Scout the field throughout the season
- Process trial data and return it to the farmer
- Data (excluding spatial data) will then be summarized and complied with other data.

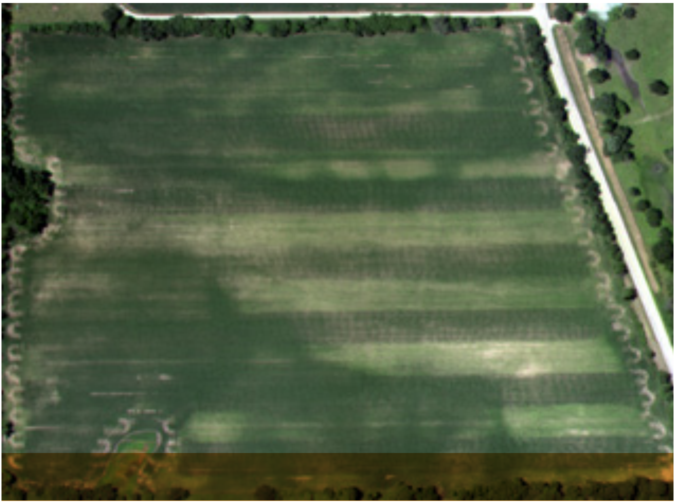


Figure 2.1 – A two-treatment sulfur trial established in a corn field with large spatial variability in soil organic matter and sand content in eastern Iowa. The early July corn canopy showed the potential sulfur effect in the upper portion of the field within sandy soils.

FIELD AND LOCATION SELECTION

Field selection for trials depends on the product or practice being tested. Some trials are targeted to specific geographical areas or in field areas that have specific characteristics. For example, areas with low soil pH, fields with a disease history or those located within watershed boundaries. Farmers can work with their consultant, agronomist or research group to determine which fields would best suit specific trials.

Fields with significant soil variability, as seen in Figure 2.1, are targeted for specific trials.

Individual plots or strips that receive treatment applications are often called experimental units. For example, an individual pass of a fertilizer applicator or planter across the field will often be considered an experimental unit. Occasionally, experimental units may have two or more planter or combine passes (Fig. 2.2).

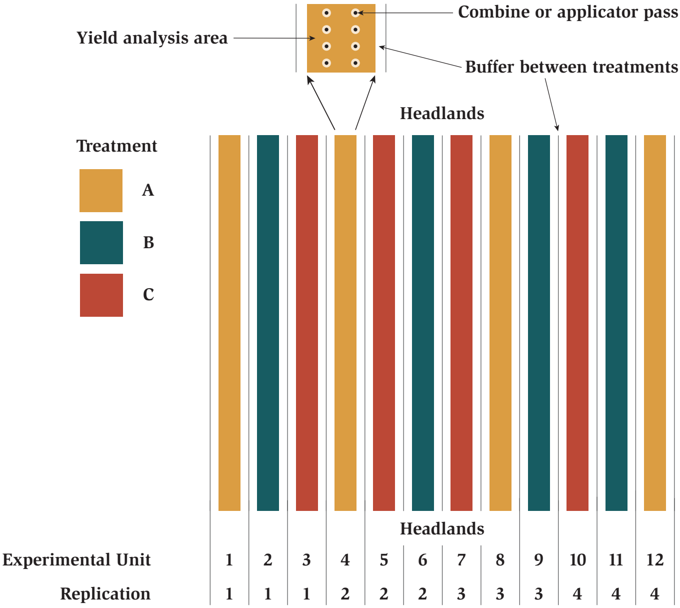


Figure 2.2 – Schematic illustration of an on-farm trial with three treatments (A, B and C) within a field. The three treatments are randomly assigned to 12 experimental units in each of the four replications.

The number of available experimental units within a field determines how many replications are possible.

A replication is a physical repetition of experimental units with the same comparative treatments or factors across a field (Fig. 2.2). Replications are needed to quantify the variability among experimental units or strips with the same treatment. This variability is often called standard error or noise. Standard error is variability not explained by the treatments, such as spatial variability, measurement error, environmental conditions, equipment issues and human error among others.

Farmers often will compare treatments by splitting a field into two parts, known as the side-by-side method, wherein part of a field is one treatment and another part is a different treatment. Because these comparisons are done without replication they do not allow for the assessment of within-field variability and noise. Assessment of within-field variability is important when making statistical inferences and extrapolating results to the entire target area.

It is highly recommended to replicate all treatments four or more times in each trial, as shown in Figure 2.2.

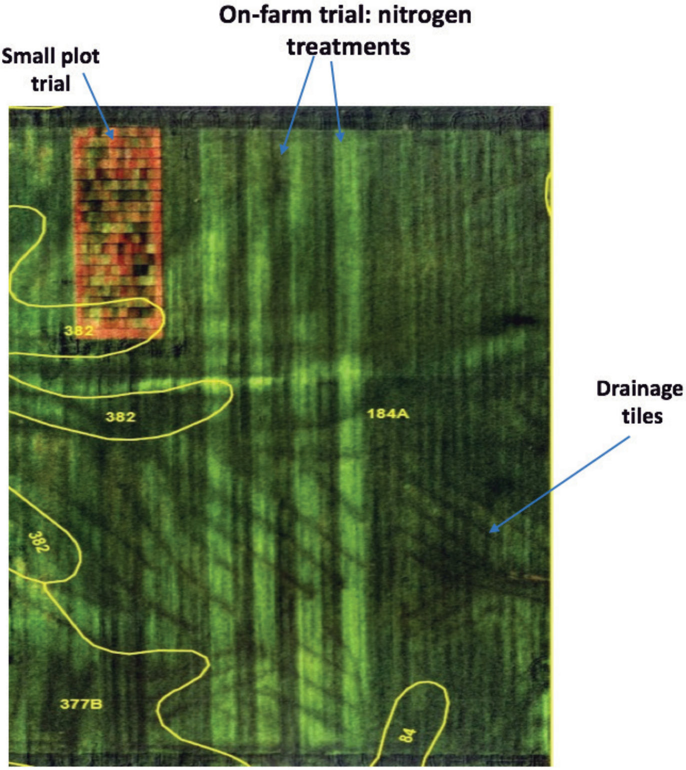


Figure 2.3 – A field with small-plot controlled experiment in the upper left corner and on-farm replicated strip trial with two nitrogen fertilizer rate treatments shown in the center. The dark angled lines indicate the location of drainage tiles. The dark vertical strips are side-dressed applications. Notice that because of plot size, the drainage tiles may impact yield variability more in small-plot than in on-farm field-scale studies.

Experimental units, often called strips, should span the length of the field. Some types of trials require more than four replications to capture the entire field for spatial analysis of yield responses.

The following suggestions should help in planning on-farm replicated strip trials.

1. **Keep it simple —** Compare only two or three treatments in a single replicated strip trial. Too many treatments applied by wide equipment will limit the number of replications within a field.
2. **Replicate treatments —** Replicate each treatment a minimum of four times in the trial. Avoid placing treatments in headlands that typically have increased traffic, pest infestation or the potential for soil compaction.
3. **Keep other management consistent —** Keep all other management practices, except those used in treatments, the same within the replicated strip trial area. This includes using the same hybrid or variety, seed treatments, planting dates, harvest dates, weed or pest management, etc.
4. **Avoid bias —** Use randomization whenever possible and use personal knowledge of within-field variability or within-field management history to reduce the chance of all experimental units with the same treatments being located within the same spatial patterns of previous management, drainage tiles or trials from previous years.

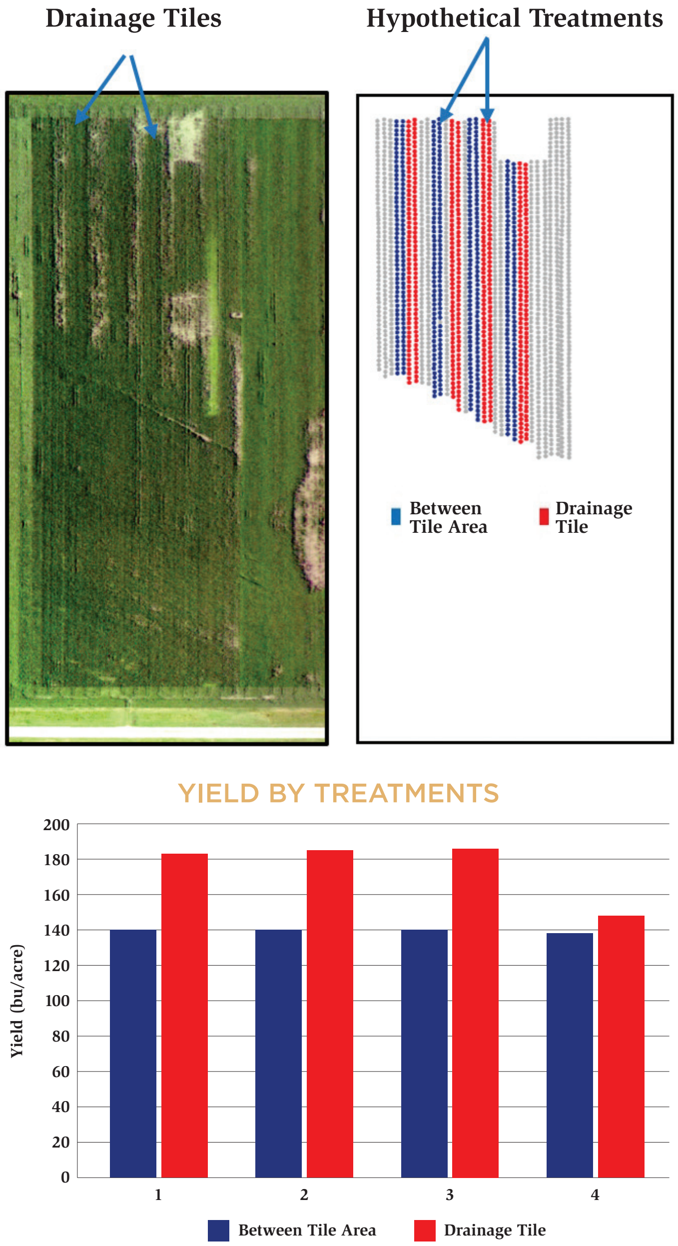


Figure 2.4 – Potential bias in estimated yield differences produced by the direction of drainage tiles that coincide with the treatment direction.

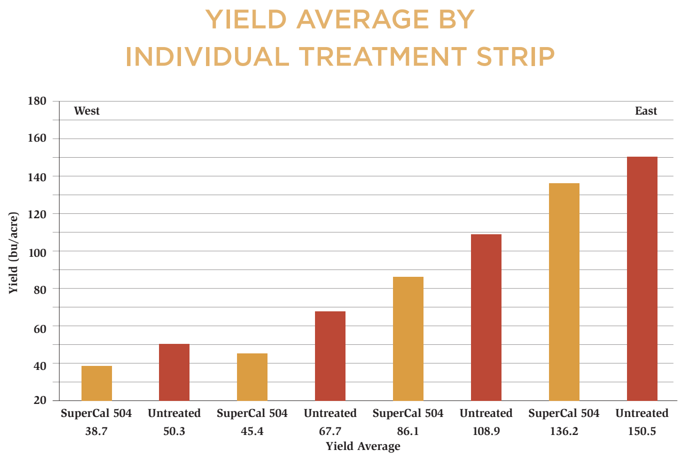


Figure 2.5 – Potential bias in estimated yield differences produced by a spatial trend, which is often caused by gradual changes in soil properties from one side of the field to another.

RANDOMIZATION

Randomization considers chance when assigning treatments to experimental units. The old way to randomize treatments was to flip a coin or draw treatment labels from a hat, today randomization software is used.

There are three main reasons why randomization is recommended:

1. To avoid bias from management practices, manure application, previous field boundaries, extremely variable fields, irrigation, residue distribution and pest pressure along with many other factors (Figs. 2.4 and 2.5). Each of these can create a bias problem. Farmers' personal knowledge of within-field variability is often just as important as random treatment assignment.
2. To draw conclusions from the data and help researchers use a wide range of common statistical

analyses such as analysis of variance (ANOVA) and regression.

3. To neutralize, balance or disperse the effect of spatial variability across the trial. However, a common objective of many on-farm replicated strip trials is to quantify the effect of spatial variability on yield response in order to evaluate or develop site-specific recommendations.

While the benefit of randomization is well recognized, potential challenges may arise in on-farm trials when randomization is used for treatments without buffers. Buffers are adjusted areas/strips that are not used in data summaries or to which no treatment is applied. These buffers are established between treated areas in order to avoid cross-contamination (Fig. 2.2). A common situation in on-farm trials without buffers occurs when randomization puts one strip with the highest nitrogen (N) rates side-by-side with a strip with one of the lowest N rates. This results in plants from the edge rows of lower N rates robbing N from those with higher N rates. When the equipment (planter, applicator or combine) width lines up just right, it may be impractical to have buffers in on-farm trials with a wide

range of application rates.

The same requirements of field selection, treatment replication and bias reduction exist for on-farm trials with more than two treatments. More-than-two-treatment trials can be done by applying one set of treatments perpendicular to the rows and the other set of treatments in the same direction as the rows (Fig. 2.6). The width of the treatments across rows should be at least 300 feet in order to receive reliable yield monitor data and establish buffers between treatments applied perpendicular to the row.

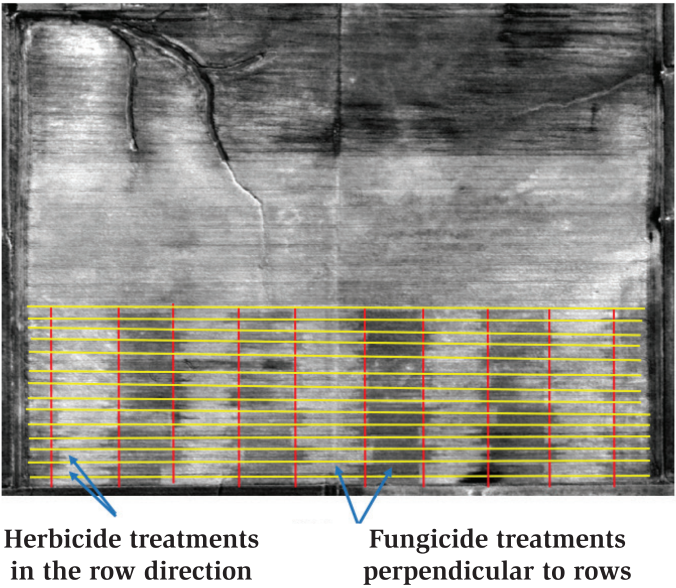


Figure 2.6 – An example of an on-farm trial studying effects of two factors: fungicide vs. untreated against the rows and residual vs glyphosate treatments (with the soybean rows). The fungicide treatments, shown as vertical light blocks on the near infrared band of aerial imagery span across soybean rows in five replications and were done by driving the sprayer along the rows. The residual herbicide and glyphosate treatments, span in the direction of soybean rows in seven replications. The aerial imagery taken in the end of the growing season shows the delay in fungicide applications as the sprayer reached the target areas for treatment applications.

Chapter 3:

ON-FARM TRIAL TYPES

The On-Farm Network conducts different types of trials testing products and practices. In this section, there will be topics including planter types, aerial application, nutrient application, tillage and sprayers. Trials are divided up by equipment needed for implementation. Many trials are easy to setup and can be done using farmers' equipment.

PLANTERS AND DRILLS

Planters are used in different on-farm trial categories. The On-Farm Network conducts planter trials on both corn and soybeans. A corn trial implemented with a planter is one of the easiest trials to complete because treatments often match the combine header width. Soybeans on the other hand, can be more difficult to execute because of the size differences between soybean planters and combine headers. Planters equipped with variable rate drives, hydraulic downforce, insecticide boxes, in-furrow liquid applicators or other technology are well suited to setting up different types of trials.

Trial types:

Seeding rate — Seeding rate trials, including plant population and variable rate seeding (VRS), as the name indicates, involve varying seeding rates in replicated strips across the field. Seeding rate trials are designed to determine when and where the farmer's normal seeding rate can be adjusted to produce an economic return. For example, in a two-treatment soybean planting trial, the seeding rates often differ by 25,000-40,000 seeds/acre.

The objective of VRS trials is to test the different seeding rate recommendations, based on historical yield data, yield potential, soil types and other factors. Farmers often test variable rate prescriptions by comparing them to a single or fixed seeding rate across a field. One option is to compare VRS to a normal seeding rate by using a VRS prescription in the planting monitor (electric or hydraulic drives required).

Seed treatment — Seed treatment testing includes products such as insecticides, fungicides, nematicides, inoculants, micronutrients, biologicals, stimulants and various other products. With many treatment options, it is important to have a check treatment that uses the same base seed treatment (fungicide and insecticides for example) without the product being tested. With this type of trial, it is important to have both treatments use the same hybrid, variety and ideally seed lot number. These trials can be planted with a split-planter or by planting the first treatment in strips and then filling in the remaining strips with the second treatment.

Row spacing — Row spacing trials, in corn or soybeans, can be completed in multiple ways: two different planters, off-setting the planter with GPS and auto-steering or turning off rows in an interplant or narrow spaced planter. This type of trial should be harvested with the rows.

In-furrow — If a planter is equipped with liquid or dry in-furrow application options, then insecticides, fungicides, biologicals or fertilizers can be applied while planting. These trials can be completed with a split-planter, prescription or by manually shutting off passes.

Trial implementation:

Split-planter — Split-planter trials are when a farmer sets up treatment comparisons with different sections of the planter. While the most common type is a two-treatment trial, three treatments are not uncommon. This is considered one of the easiest trials to implement because once the planter is loaded, farmers can replicate the entire field. Split-planters provide farmers with many trial options including downforce, soil-applied insecticides, seed treatments and starter fertilizer, among others.

Prescription — If a planter has electric- or hydraulic-drive capabilities, a treatment prescription can be loaded into the planter monitor to control rates or activate application of products. The prescription

is communicated to the planter eliminating the need for farmers to manually adjust seeding rates or other treatments.

Manual — Farmers can plant alternate passes with one treatment and then come back and plant the skipped passes with the second treatment, manually turning the in-furrow applicator on or off every other pass or manually adjusting seeding rates on ground-driven planters.

Other trials, such as soil applied insecticides or starter fertilizers also can be implemented by manually turning on and off passes with the treatment in a replicated-strip pattern.

Considerations:

While planter trials are relatively easy to set up, having a harvest strategy is important. For more information about implementing a successful harvest strategy, see the Harvest section in chapter four.

SPRAYERS

Sprayers are used to apply foliar fungicides, insecticides, herbicides, biologicals, micro- and macronutrients, etc., to both corn and soybeans. Similar to planter trials, sprayer trials are typically very easy to execute.

Trial types:

With-row application — This is a simple trial type that can compare two or more treatments sprayed with the rows. An example would be treated versus untreated strips replicated at least four times across the field. Another option for farmers wanting to harvest soybeans at a slight angle is to apply the treatment in wider swaths to ensure quality data can be collected.

Not-with-row application — A sprayer application does not have to go with the rows to be a successful trial. Options include applying product perpendicularly to the rows in 300-foot strips or applying product in the direction the crop will be harvested.

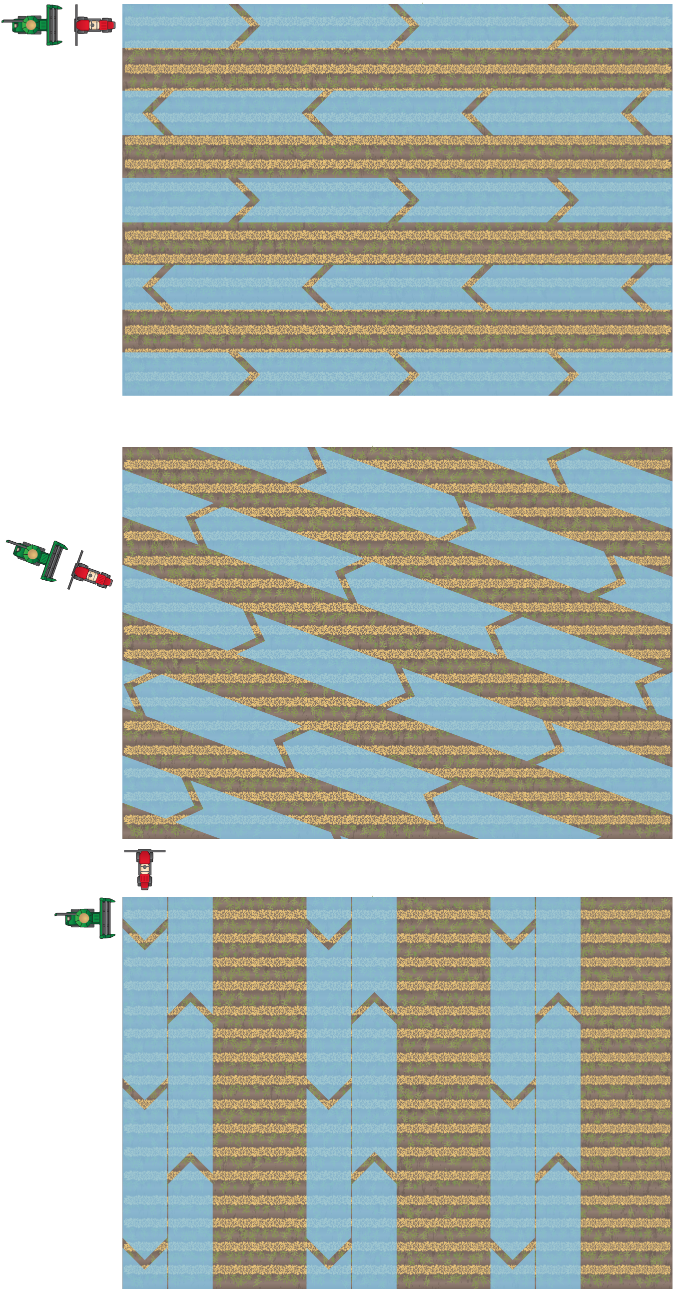


Figure 3.1 – These graphics show the various options farmers have when implementing a sprayer trial.

Considerations:

While sprayer trials can be easy to execute, there are several key details to remember

1. **Application timing —** Many products have a suggested or required growth stage for application. Incorrect timing may result in no treatment effect or potential yield loss.
2. **Product mixing —** Combining multiple products can save cost and time, however it is important to ensure the products being mixed are compatible and do not have a negative effect on crops. For proper control, sometimes it may be appropriate to compare product A versus Product A plus B. For this reason, it is important to obtain and follow label and/or protocol directions.
3. **Application method —** Spraying trials that are applied with an aerial applicator instead of a sprayer or high-clearance applicator may be more difficult to process due to potential drift and swath width differences.

NUTRIENT APPLICATORS

These on-farm trials study rate, form, time and placement of nutrients and are implemented using fertilizer carts, floaters, manure injectors, tool bars or in-season high clearance sprayers. Nutrient application trials can be successful on both corn and soybeans. It is preferable to use GPS and flow-meter capable equipment. Depending on application timing and the number of treatments, the complexity of the trial may vary.

Trial types:

Dry fertilizer applicator — These trials can compare different fertilizer application rates, forms, timings, nitrogen stabilizers, soil amendments and residual effects of fertilizer. Trials are implemented to test products and practices intended to maintain soil fertility and productivity. Soil or tissue sampling is often done to monitor the effect of the treatments over time. Some examples of fertilizer trials include urea, lime, sulfur or potash rate trials. If farmers do not have their own equipment, a local cooperative may be able to help with treatment application.

Manure applicator — Different manure types require particular application methods. Both injection and surface-applied techniques can be used if properly applied. Rate, placement, timing, stabilizers, additives and a combination of manure and commercial fertilizers are the most common types of manure trials. For a successful comparison, surface-applied and injected manure strips must be wider than a full combine pass. If the manure applicator is not wide enough, multiple application passes can be used. Manure applications should follow local or state regulations.

Nutrient toolbars — Nutrient treatments can be applied in the fall, spring or in-season and in different fertilizer forms. Nutrient toolbars are used to compare rates, timing, forms, placement, stabilizers and additives. Examples are fall vs. spring and anhydrous ammonia (NH_3) vs. urea ammonium nitrate (UAN). If farmers do not have their own equipment, local cooperatives may help to apply fertilizer treatments.

Liquid nutrient applicators — See “Sprayer,” “Planter” and “Aerial Application” sections to learn more about liquid nutrient application.

Considerations:

1. **Nutrient Toolbar calibration —** It is important to ensure that the NH_3 or UAN toolbar is properly calibrated and will apply fertilizer at the desired rate. Often, rented or new equipment should be adjusted. Ensure the product output is the same on each row or nozzle.

2. **Product drift —** For trials with dry and liquid fertilizers, wind speed can create challenges when applying replicated strips. If a product is applied on a windy day, the product applied in the replicated strips may not be as accurately placed as desired. Try to apply on a less windy day, or create wider strip swaths to account for potential drift.

3. **Spreader swaths —** Spinner spreaders are often designed to have overlapping swaths. If a single pass is used for a treatment, the edges of the swath may receive higher rates of product than the center of the swath. Proper calibration should reduce inaccuracies with spinner systems that could distribute product inconsistently.

4. **Pipeline manure injection system (umbilical cord) —** Applying manure with an attached pipeline can pose significant challenges during trial implementation due to difficulty of changing treatments and applying them in the row direction.

5. **Lack of GPS —** Many nutrient application machines do not have the advanced GPS capabilities of a planter-tractor, sprayer or combine. It is important to record application data for soil sampling and treatment analysis at the end of the year.

AERIAL APPLICATORS

Both airplanes and helicopters are used to apply insecticides, fungicides, growth stimulators, nutrients and to seed cover crop. Aerial applications allow testing of products during mid- to late-season.

Fixed-wing aircrafts — Aircraft can be used for in-season product application without damaging the crops. Treatments applied by aircrafts should be wider than one pass to ensure uniform coverage because the aircraft delivery system is specifically calibrated to overlap one pass with another. Also, multiple aircraft passes will ensure that the treatment is wider than a full combine pass.

Helicopters — While providing similar benefits as fixed-wing aircrafts, helicopters can apply nutrients, pesticides and plant cover crop seeds within fields. They can maneuver better around trees, power lines and other obstructions. Helicopters have a relatively limited payload capacity but can reload and refuel at the edge of the field.

Considerations:

1. **Product drift —** Both wind and applicator speed can create challenges when trying to establish replicated strips. If a product, especially a cover crop mix, is applied on a windy day, the product applied in the replicated strips may not be as accurately placed as desired. To address this, create wider strip swaths to account for potential drift.
2. **Application altitude —** Depending on field layout and surrounding obstacles (e.g. wind mills, trees, cell phone towers), aerial applicators may not fly at a consistent altitude and may not be able to apply to a full field. Try to select fields with fewer obstructions and long, straight rows to maximize trial success rates.
3. **Spatial data —** Many aerial applicators use light bar technology, but do not necessarily record their application data. Verify with the applicator before establishing a trial that spatial data can be recorded to ensure the trial is successful and product is applied in correct locations. If the applicator does not

have the technology, try to provide a trial layout so the pilot can follow the necessary protocol.

TILLAGE

Tillage trials are usually established in the fall or spring, therefore, the time window is wider than for other types of trials. Tillage passes should go with the rows, if possible, to ensure one or multiple combine swathes. If the field is tilled at an angle, tillage passes or strips should be wide enough to collect yield data.

Trial types:

Comparison of two tillage practices — This type of trial can be completed in the fall, spring or both. Examples include vertical tillage vs. conventional tillage, field cultivator vs. disking and strip-till vs. conventional tillage.

Comparison of tillage vs. no-till — The treatments can be monitored for one year or over several years. Examples include no-till vs. conventional or strip-till. Planter set up should be considered to ensure proper

coulters or row cleaners are installed and springs are adjusted for different soil conditions.

Considerations:

1. **Multiple implements —** Comparing two different tillage methods, such as vertical tillage vs. chisel, requires different equipment. Implement width, tillage depth, machine compaction and other factors need to be considered to reduce or eliminate potential errors in the data. Ensure implement widths are wide enough to allow full planting and harvest passes.
2. **Planter configuration —** Two different tillage methods may require adjustments to the planter to properly manage residue, soil penetration, seed-to-soil contact and closing the trench. Sufficient weight and ground contact must remain on the gauge wheels to ensure firming of seed into the soil for an even plant stand.

Chapter 4: HARVEST DATA

A trial is not complete without collecting GPS-enabled yield data. Best results are captured with a properly calibrated yield monitor. While weigh wagons can be used to calibrate yield data, the On-Farm Network uses only spatial yield monitor data.

It is important to consider in advance how the treatments will be harvested. Farmers should have a harvest plan for each trial before going to the field in the spring.

- Ensure that the entire trial can be harvested on the same day
- Use one combine to avoid calibration differences among different machines
- Make sure the combine header width lines up with each treatment to have full, or complete, harvest passes

Tips for harvesting a trial:

1. **Firmware updates —** Ensure the yield monitor firmware is up-to-date and the GPS receiver is transmitting properly. Trial data can be lost due to simple monitor software issues during the season.

2. **Calibration —** Yield monitors should be calibrated for each new crop, hybrid and moisture level. For example, monitors should be calibrated differently for corn with below 20 percent moisture versus corn with above 20 percent moisture. In addition, each monitor will have its own calibration recommendations found in the owners' manual.

3. **Header/swath width —** The planter and combine header widths must be compatible in order to properly capture the data from the treated experimental units. If a trial with an experimental unit width of 30 feet is harvested with a 40 foot-wide combine header, plants from an untreated buffer or the neighboring, differently treated experimental unit, may be mixed in.

4. **Harvest angle —** While harvesting soybeans at an angle is a common practice used to minimize wear on the soybean combine header, harvesting at too much of an angle, or harvesting through narrow trial strips can result in the loss of harvest data. It is important to try to harvest trials with the rows. If this is not possible, planning ahead and establishing wider treatments, along with minimizing the harvest angle, can help negate this problem.

THE ON-FARM NETWORK QUALITY CONTROL METHODOLOGY

The On-Farm Network uses a thorough quality control (QC) process to ensure that each trial meets the established standards.

Tools and data layers used:

1. As-applied or as-planted data for each trial are recorded with a GPS-enabled monitor
2. Aerial imagery is taken of each field toward the end of the season
3. Yield data is collected with a combine equipped with a GPS-enabled yield monitor

Quality control process:

As-applied or as-planted data, yield data and imagery are layered using GIS software and a clean harvest pass is selected. A clean harvest pass is a pass within one treatment, with the same hybrid and variety, harvested on the same day and with all other factors, except the treatment being studied, kept constant. Yield observations for the headlands and approximately the first 50 feet of each pass are removed to adjust for combine flow delay.

The aerial imagery is then used to map ponding areas and to identify hybrid or variety changes, nitrogen skips and other management or equipment issues that may have affected some treatments but not others within the trial. If other factors are found to be affecting the yield data of one treatment, the corresponding data from all the other treatments should be removed.

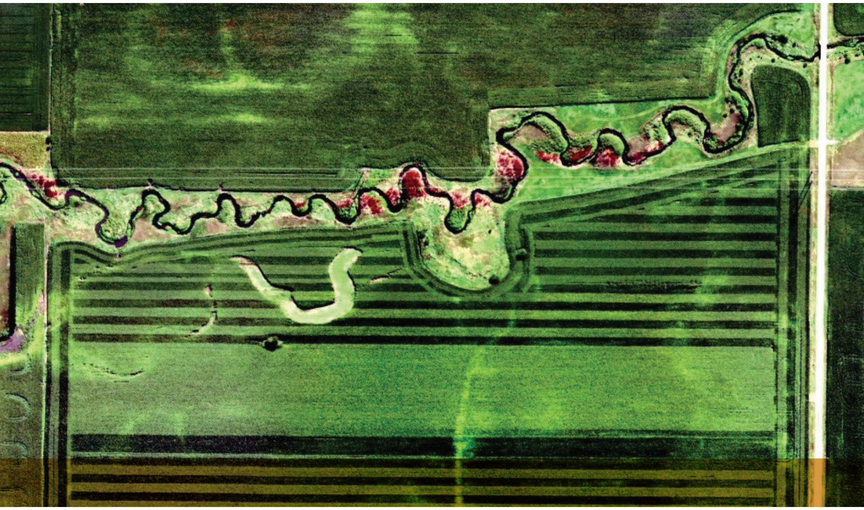


Figure 4.1 – This aerial image shows ponding areas in the top half of the field. They will be removed from the trial data.

Yield data contain several attributes that are crucial to the QC process: bushels per acre (bu/acre), harvest date, grain moisture and combine speed as well as crop variety and hybrid.

- **Yield —** In the QC process, outliers, or extreme, yield data expressed as bu/acre, are removed to ensure more accurate results. When grain reaches a flow sensor, the initial impact often causes the yield monitor to register a very high bu/acre value. Other times, when the combine header is left running while not actively harvesting, the yield monitor will report zero bu/acre for several GPS points.

- **Harvest date —** The entire trial should be harvested on the same day to maintain minimal differences in grain moisture and combine calibration. If same-day harvest is not feasible, care should be taken to harvest the complete replication on the same day.
- **Moisture —** Due to yield monitor calibrations, detecting drastic changes in grain moisture (2 percent or more) is an integral part of the QC process. If moisture varies significantly from the calibration level, the reported yield values may be higher or lower than actual levels.
- **Hybrid/variety difference —** Due to inherent differences in yield potential among varieties, the same hybrid or variety should be planted across the whole trial. While it is not preferred, if multiple hybrids are present and the number of replications in each hybrid is sufficient, a trial may still be used.
- **Combine speed —** During harvest, consistent combine speed is essential because drastic speed changes or deviation from the yield monitor calibration speed may affect yield and therefore treatment yield differences. Treatments must be harvested at the same or at a similar speed.

If it is determined through the QC process that a trial does not meet the minimum set of requirements described above, the report will not be made public or used in analysis. If available, farmers will still be given their individual data.

The On-Farm Network is committed to providing farmers the most detailed and accurate data. As part of their research plan, many of the trials will be scouted throughout the season to help explain yield differences between the treatments observed at the end of the season.

Products and practices are generally evaluated based on the yield differences at the end of the season, but the yield itself may not tell the whole story. For example, if insecticides were applied in a year with little pest pressure it's unlikely the product had an impact on yield. It is important to consider environmental conditions of specific treatments or products when evaluating their effects on yield.

Data collected by the On-Farm Network includes rainfall data received from either statewide reports or field-specific weather stations, plant population counts, disease ratings, soil sampling and aerial imagery. All these scouting data allow the ISA Analytics team to identify when and where the studied practices or products impacted the crop yield or yield response.

Chapter 5: HOW TO USE ON-FARM DATA

DATA ANALYSES AND RESULT INTERPRETATIONS

Synopsis

While there are many different tools to conduct statistical analyses and summarize data, farmers, consultants and even scientists alike are often frustrated by this process. To reduce this common hesitation during data analyses, brief discussions below are focused on three key statistical tests. A paired t-test is discussed because it can be easily done by anyone proficient in Microsoft Excel for two- or even three-treatment trials. For trials with multiple (three and more) treatment comparisons, a very short reminder is written about the least significant difference (LSD) test, and how to use it appropriately. A randomization test is discussed first because it is formula free and should intuitively explain the origin of p-values, which are used to draw conclusions with many statistical tests including a paired t-test and LSD test.

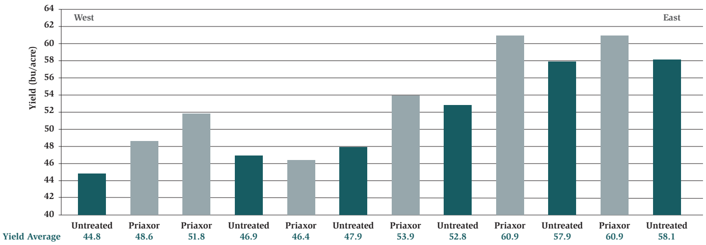
While most often the data from each on-farm trial are analyzed separately, it is important to pool data from multiple locations. Finally, this section ends with a brief discussion on the break-even and risk analyses for yield response data.

Two treatment comparisons: randomization test

The basic idea of a randomization test is to identify how likely or unlikely the observed average yield difference is caused by random noise or by treatment effects. Figure 5.1 shows yield summaries from a strip trial with fungicide treatments on corn in 2014. The trial had two treatments, “A” (fungicide) and “B” (untreated control). There were six replications within the field. The bar plot represents yield averages for the 12 experimental units as they occurred across the field, from west to east.

The histogram of random noise is produced by entering yield data into a computer program and then instructing the computer to forget the labels assigned to each experimental unit or strip. The strip means are rearranged into all possible combinations thousands of times, while keeping each replication pair together. Because the computer program is unaware of which treatment is which, all estimated paired yield differences between the rearranged strips result in the histogram, called random distribution of noise in (Fig. 5.2).

If the combined area to the right of the observed yield difference of plus 3.1 and to the left of minus 3.1 on the histogram of random noise is not extremely small (greater than 5 to 10 percent) based on the selected significance level), chances are that the observed yield



Yield Average for All Individual Treatments (bu/acre)	Priaxor 53.7	Untreated 51.4	Yield Difference 2.3	A randomization test suggested some evidence of a significant yield difference.

Figure 5.1 – The evidence of significant yield difference depends on the number of replications and the variability within fields. With the same within-field variability, on-farm trials with a larger number of replications will more likely show a significant yield difference. A non-significant effect has two potential meanings. Either there is no true treatment effect or the effect is undetectable due to large variability or too few replications.

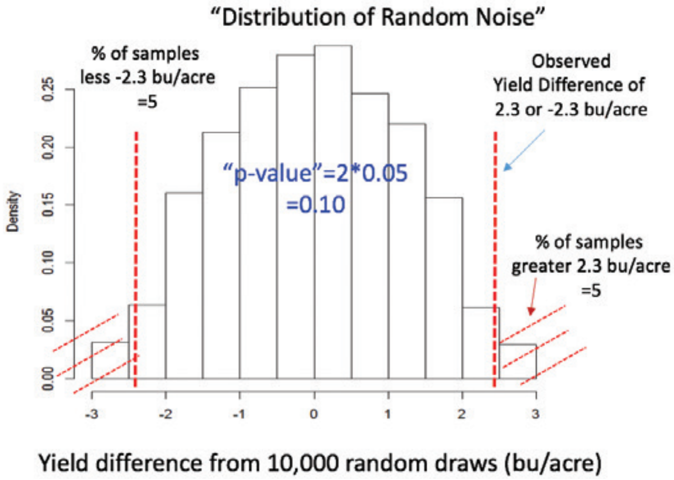


Figure 5.2 – Example of identifying significant yield difference between two treatments using a randomization test.

P-values from different statistical tests are commonly classified into the following categories:

- *>0.10 — no evidence of significant yield difference*
- *0.05-0.10 — some evidence of significant yield difference*
- *<0.05 — strong evidence of significant yield difference*

difference is the result of random noise and not the effect of the treatments. If, however, the combined area to the right of plus 3.1 bu/acre and to the left of minus 3.1 bu/acre is extremely small (less than 5% or greater than 10 percent), then we can claim that the yield difference is due to treatment effect and is statistically significant. The smaller the p-values, the greater evidence of significant yield difference.

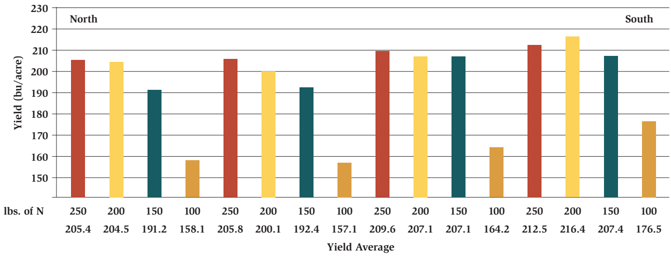
Paired t-test for two-treatment trials

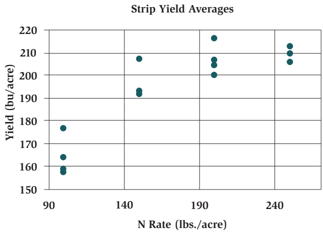
If experimental units or strip averages are not enough to make a visual assessment of whether or not the yield difference is significant, a paired t-test can be done in Microsoft Excel. Refer to the Excel help menu for instructions. Paired t-tests are based on the same logic as the randomization tests, but the distribution of random noise is expressed by a mathematical formula.

Multiple treatment comparisons: Least significant difference (LSD) test

When on-farm trials have more than three treatments, using the randomization or paired t-test becomes difficult. Historically, the LSD test has been one of the most commonly used in agronomic studies. The basic idea is to generate a number that will tell whether the treatment difference meets a threshold of significant difference.

For an LSD test, treatments are marked with the same letters if they are not statistically different or marked with different letters if they are different. For example, Figure 3 shows that at 10 percent significance level, yield differences among the three lowest N rates, 100, 150 and 200 lb N/acre (all three have different letters such as “a”, “b” and “c”) are significant while the yield difference between the two highest N rates are not.





Treatment	*Avg. Yield*
100 lbs. N	164 c
150 lbs. N	200 b
200 lbs. N	207 a
250 lbs. N	208 a

Least Significant Difference ($LSD_{0.10}$) = 5.2 bu/acre

Treatments with the same letter are not statistically significant at 10% significance level.

Figure 5.3 Example using the least significant difference (LSD) test for identifying significant yield differences between treatments with four nitrogen rates (the data provided by Indiana InField Advantage in 2014).

The caution is that the LSD values should be used only when at least one pair of N rates has significant yield difference. Otherwise, the test can claim significant yield differences when they are not present. The LSD test is very conservative when only a few pairs have different means. There are a dozen tests similar to LSD; each can potentially produce different results.

Economic analysis of aggregate data

The On-Farm Network has an online database of on-farm strip trial results that enables users to estimate average yield differences between treatments for different categories of trials. For example, the average yield difference for two soybean seeding rates — 130,000 and 160,000 seeds/acre — based on 13 on-farm trials in 2013 was 0.8 bu/acre. The 95 percent confidence interval for this average spanned from 0.2 to 1.4 bu/acre. The logic behind this interval is in hypothetical frequencies. If these trials were repeated in the same conditions an unlimited number of times, the yield response would fall between 0.2 and 1.4 bu/acre 95 percent of the time. Because this confidence interval (0.2 to 1.4 bu/acre) does not include zero, the average yield difference of 0.8 bu/acre can be considered statistically significant.

Another useful feature of the online database is that it allows users to estimate return-on-investment (ROI) for different crop market prices and variable input costs per acre. In the example with the soybean seeding rates in 2013, the average ROI was about minus $1/acre considering a $9/bu soybean price and with an additional seed cost of $8/acre.

While results of the statistical tests described above are useful, their utility is often limited, especially when making management decisions. To make better management decisions, the economic analysis can be combined with the risk analysis.

Risk analysis allows researchers to focus on the whole distribution of potential yield responses estimated for a new or unobserved field considering data from multiple locations or several years. These predicted values are estimated using the observed within and across field variability in yield response. The predicted yield response for increasing a farmer's normal soybean seeding rates by 30,000 seeds/acre from 130,000 seeds/acre spanned from minus 2 to plus 4 bu/acre for fields planted before and after May 20. This range is larger than one generated from the online database because to make predictions not only observed but also future variability

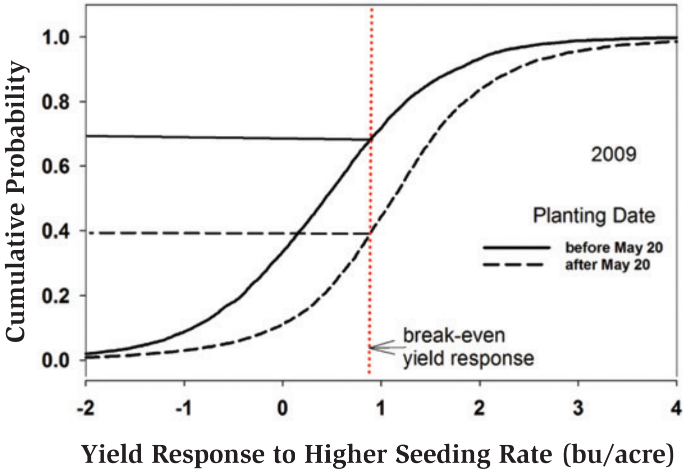


Figure 5.4 – Field-level predictions of yield responses for unobserved or new situations. The probability curves were derived using yield differences estimated at 100-feet grid patterns within each of the on-farm trials.

in yield response should be considered.

The "S-shape" probability curves show a 60 percent chance of yield responses above the break-even yield response (0.9 bu/acre) for fields planted after May 20, and a 30 percent chance for fields planted before May 20 (Fig. 5.4). The break-even yield response shown as the red line can be moved to the right if seed costs increase or soybean prices decrease. It can be moved left if the seed costs decrease or soybean prices increase. The two probability curves do not intersect, indicating strong evidence of potential yield response with later, compared to earlier, soybean planting.

Finally, it is always useful to conduct economic analyses, even if there is little evidence that yield differences are significant. The key to appropriate interpretation of results from on-farm trials is to consider appropriate data, conduct economic and risk analyses, and of course, the use of common sense.

ADDITIONAL RESOURCES

ADDITIONAL RESOURCES

Readers wanting more information or more detail about a specific topic are encouraged try these additional resources:

On-Farm Network replicated strip trial database

Every year, the On-Farm Network completes hundreds of trials. The results are loaded into the database and can be searched by crop type, product, county, watershed and many other factors ensuring farmers get the information they are looking for. Certain practices have been studied so extensively that the ISA Analytics department has setup a ROI calculator that allows farmers to see their return based on their input costs and the current commodity price. To access the database, visit ***www.isafarmnet.com*** and look under the "research results" tab.

ISA Research Advance

Research results right at your fingertips. The ISA Research Advance is a weekly e-newsletter focusing on topics designed to make farmers more profitable. Articles are written by all three teams that make up ISA Research — the On-Farm Network, Environmental Programs and Services and Analytics — as well as guest columnists from other research entities. To subscribe to the Advance newsletter, visit ***www.isafarmnet.com*** and look under the "publications" tab.

ISA Research Conference

The latest research findings from agronomic and environmental studies are presented at the ISA Research Conference annually. Held in mid-February, this conference is one of the premier research conferences in the Midwest and features presentations from ISA's three research teams, Iowa State University and many other researchers from across country. For information about how to attend the conference, visit ***www.isafarmnet.com*** beginning in December, or subscribe to the Advance for regular updates.

On-Farm Network peer-reviewed and technical publications

Summaries of on-farm trials conducted across multiple years can be found in peer reviewed papers and other technical publications.

Iowa State University

The On-Farm Network works with many departments at ISU to collaborate on research. The specific expertise provided by ISU and the Iowa Soybean Research Center at ISU are invaluable to the On-Farm Network.

Other inquiries

If there are any other questions about current or future research, please call the On-Farm Network at **1-800-383-1423**.

GLOSSARY

Confidence interval — A range with the lower and upper bounds that characterize the average yield or yield response value. For example, a 90 percent confidence interval indicates that if a trial were repeated millions of times at the same location, a yield response would fall between the lower and upper bound 90 percent of the time.

Downforce — A force acting on a moving vehicle, such as a planter, having the effect of pressing it down toward the ground. Typically referenced as the number of pounds of pressure on a row unit.

Electric drive — A drive motor on a planter that operates based on an electric motor powered by the tractor battery or alternator. An electric-drive motor does not require drive chains, sprockets or clutches.

Experimental unit (strip) — Individual plots or strips that receive unique treatment applications. Experimental units can have one, two or more individual combine passes.

Floater — A general term for a fertilizer applicator with wide tires to minimize compaction.

Flow delay — The time between when the grain enters the combine header and the grain measuring device of the yield monitor.

Headlands — Within-field areas at the beginning and end of treatment applications. Before data analysis, yield observations from headlands are removed.

Hydraulic drive — A drive motor on a planter that operates based on the speed of the hydraulic-drive motor, rather than the speed of a mechanical-drive wheel.

Outliers — Extreme values that fall outside the defined or expected range. For example, yield monitor observations are considered outliers and are often removed if they fall below or above two standard deviations from the average value.

Remote sensing — A general term for collecting information about soil and plant properties without physical contact. Aerial satellite imagery is the most common types of remote sensing in agriculture.

Soybean checkoff — An investment made by farmers through the sale of their soybeans. The value of half of one percent of each bushel is collected by state organizations and then distributed evenly among national and state projects.

Spatial data — Data that have attached coordinates.

Standard deviation — A number that explains the spread of data. In a bell curve distribution, 95 percent of data fall between plus and minus two standard deviations from the mean and 68 percent of the data fall between plus and minus one standard deviation from the mean. Larger standard deviation indicates larger data variation.

ACRONYMS

ANOVA — Analysis of variance

EPS — Environmental Programs & Services

GIS — Geographic Information System

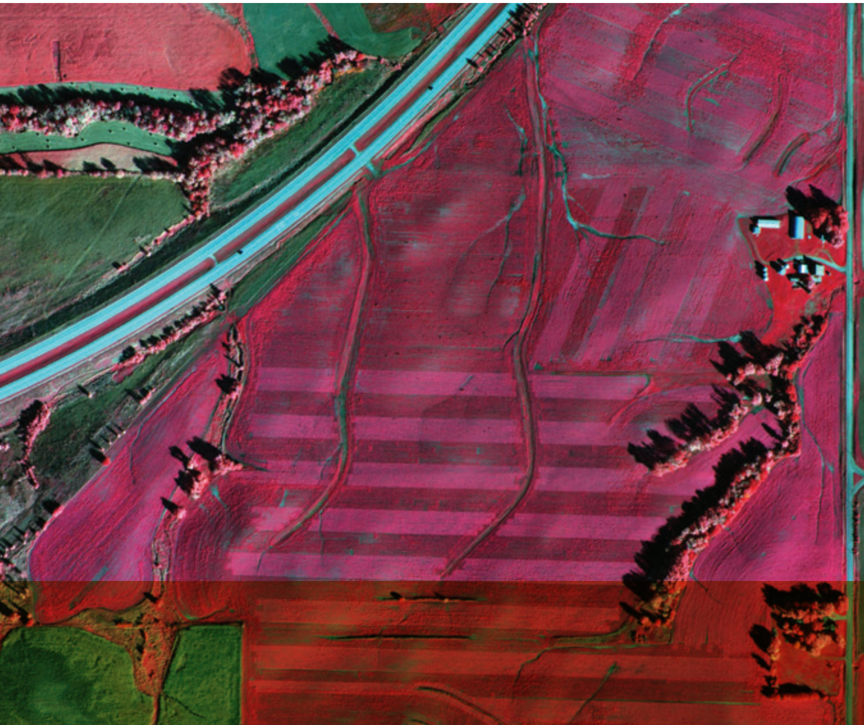
GPS — Global Positioning System

ISA — Iowa Soybean Association

LSD — Least significant difference

ROI — Return on investment

VRS — Variable rate seeding



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