should not be applied to control *R. cerealis*.

These fungi produce sufficiently different symptoms that a superintendent can tell the two apart – but not without some testing first. When the irregular yellow rings show up, spray as you would normally (for Rhizoctonia, Prostar is a good choice). But this time, place a piece of plywood over some of the irregular yellow circles before spraying so that nothing is applied to these areas – the non-treated control plot. Mark the location of the corners of the plywood using turf paint so the non-treated areas can be easily identified for three to four days. Observe the plots daily for several days and record your observations. In this case, what would the objective of the study be? Can you list the materials and methods for the study proposed? What might the outcomes be? How much money might you save if the irregular yellow rings disappear in the non-treated control plots – and why?

Record Keeping

The foundation of any testing program is record keeping. Before starting any testing program buy several composition notebooks at a stationery store. These notebooks are inexpensive and they will provide a reliable place to keep a chronological log of your testing programs. Leave a few pages blank at the beginning of the book to use as an index. Use only ballpoint pens that do not have water-soluble ink. Tape a business card into the inside cover in hopes that someone will return the record book if it is misplaced. Write freely in the book any observations that you have regarding the performance of a product, the reaction of golfers to a management practice, or difficulty handling or applying a material. Excess information is better than insufficient information. This notebook will be the object of discussion in resolving disputes about which practice or technique is best and where or how a product was applied. Date each entry and take notes carefully so that your efforts are not wasted.

Stay tuned for the next installment of A Guide to Testing Products and Management Practices for Golf Course Superintendents: Part II Experiment Design. You will find out that it is easy to set up a meaningful experiment and even easier to design an experiment that leaves you with more questions than you had to start with. Keep It Simple Superintendent!

Part 2, Experimental Design

In Part 1, Getting Started, we left off with record keeping. This installment of How to Test Products and Practices will pick up from that point and provide some guidelines in experimental design - how to select treatments and how many treatments makes a good trial. The information provided here is only a launching point for to get you started in an testing program. If you enjoy the process and find on-site testing has been valuable, there are a few additional sources of information that will help you develop additional testing programs (Camper 1986, Hickey, K.D. 1986, Little and Jackson 1978). Unfortunately, most of these resources do not address turfgrass systems but they do provide a variety of ideas on testing practices.

Thinking Pays Off

Spending quality time thinking about an experimental project will pay off in the end. Gather up your ideas and find some supporting research before you develop your plan. The research can be something provided by a salesman, an article in a trade journal, or a scientific publication. If you can't find any supporting research for an idea that you want to test, you haven't looked hard enough. This doesn't mean that you shouldn't test something entirely new - it means that there are few ideas that are new and you should take advantage of other people's efforts so that you can contribute information builds on the information already available. In most cases your efforts will be directed at improving or modifying an existing process or use of a product. The payoff is in better performance, cost savings, and improved turf quality.

For example, what if you have heard that nitrate nitrogen fertilization may aid in root development and reduced shot growth compared to urea and ammonium nitrogen sources. A review of the literature finds some supporting evidence (Glinski et.al., 1990) so you want to see if nitrates improve rooting in a golf green. The publication or report should detail methods that can be adapted to a test under real golf course operational conditions. In this case, the best root to shoot ratios were obtained when the plants were supplied with three nitrate:ammonium in a ratio of 3:1. Although other ratios were evaluated, why not try the best case first compared to current nitrogen fertilization and fine tune the system later.

Control the Irge

A frequent urge when starting out testing your own ideas is to test all of the ideas at once. This strategy frequently leads to more questions than answers. To be successful in answering more questions than you started with, limit the number of questions or treatments to some number that is manageable. A good starting point is to limit the number of treatments to five or fewer if possible and not more than 10 except in special cases. There will be times when you will need to exceed these numbers but be assured you will be more confident in your results when fewer treatments are evaluated in an experiment. Time spent culling out unnecessary treatments will be repaid many times over.

Break it Down

Because some questions are complex and experiments may become difficult to execute, break these projects into smaller components that are easier to manage. If you have penciled out more than 10 treatments, break the experiment into its components. For example, if you are interested in the timing and rates of application for fungicides labeled to control summer patch disease of poa greens, the top three fungicides might be evaluated at the low and high labeled rates at two times of application - preventative (before disease symptoms appear) and curative (after symptoms appear). That would be 3 (fungicides) X 2 (rates) X 2 (times of application) = 12 treatments +1 non-treated control = 13 treatments. As you can see, adding extra factors can cause an experiment to blossom into a design that will be difficult to execute and will produce results that are hard to analyze. In stead of this more complicated design, split the experiment into its component parts.

In the example above, the two main factors under investigation are rate of application and timing of application. Why not use two different greens and test the rates of application using the standard preventative application program and compare the three products at low and high-labeled rates. This study will compare the effectiveness of the three products under normal preventative application conditions. It is a seven-treatment trial including the non-treated control. The second study would only look at the high labeled rate of each product used as a curative treatment. This study is a four-treatment study including the non-treated control. By breaking the trial down, the execution of the trial and evaluation of the data at the end of the experiment are easier to handle.

Over and Over

In order to be sure that the differences observed during an experiment are the result of a treatment and not simply variation in the quality of the turf across the test area, each treatment should be repeated, or replicated. The use of replicated treatments in a small experiment allows the experimenter to evaluate the variation that naturally occurs across a test area compared to the performance of the product in the test area. In most cases, three replications should be sufficient to separate out the good from the lousy treatments. If the differences are very small between a treated and the non-treated control plots - then the test material or process probably isn't much better than the non-treated control. Three replicate plots will be sufficient to pick out the superior and inferior treatments. More than three will improve your ability to separate differences that are close together but these differences may not be large enough to improve turf quality under normal conditions.

Size it Right

The last thing you will want to hear when conducting a field experiment is "you've got small plots." We have found that the larger you can make your test plots, the less likely that the whole plot will be destroyed by a mishap. Larger plots also make sure that a disease, insect or weed will be found in the test area. The smallest plots that we recommend for on-site testing is 4 ft X 4 ft (16 sq ft). Our usual small plot size is 5 ft X 10 ft (50 sq ft). When we are more concerned about variability in the test area, performance of a product or distribution of a pest, we increase plot size to 7 ft X 10 ft (70 sq ft). For most small plot work, a 5 ft X 10 ft plot is a convenient size for a sprayer that applies a 5 ft swath width. Unexpected events undoubtedly will occur during your experiments, for example a hydraulic leak that damages half of the plot so that it is no longer usable. With large plots, the experiment can continue with the non-hydraulic-fluid-damaged areas of all plots being rated.

Split Greens or Macho Plots

If you are not adapted to small plot work or just don't want to bother with the experimental equipment, treat half or portions of greens or fairways using your standard equipment for applications. This is the best way to test a system prior to full adoption of a cultural process or product change. In this case, replication will probably have to take place on separate greens or fairways due to size of the test area. A typical test would entail splitting greens and applying a procedure to half of a green and the standard treatment to the other half of the green. As mentioned in part 1 of this series, plywood can also perform a valuable role by providing a non-treated area when large area is being treated.

Role of the Dice

In addition to replication that helps remove the effects of variation in the test area, randomization is needed to remove our bias in locating test plots within the test area. Randomization applies to the location of each treatment area or plot within the entire area. The role of randomization is to make sure that no plots occur in the same order in each block. Randomization helps take into account any systematic impacts on the trial. For example if someone drives through the first block, the extra traffic will impact all three treatments. In the perfect world, each treatment would be replicated in each block. For our purposes, three replicates should serve the needs of identifying strong improvements in turf quality and strong detriments to turf quality.

A simple method of randomizing treatments within each replicate block is to use a deck of cards. Remove the numbered cards that correspond to each of the treatment numbers (another reason to use only 10 treatments?). Shuffle the treatments and lay the cards down in order that the treatments will be located in each block. In many cases, the first replicate will be placed in order corresponding to a treatment number in a protocol to make viewing the first replicate easier. If you need more treatment numbers, simply add numbers to several other playing cards in the deck.

The Nursery Effect

An interesting phenomenon that occurs at most golf courses is the "nursery effect." Nurseries somehow survive without disease and stress damage when most of the greens in play are struggling to survive. The lack of traffic on a nursery green makes this area a poor candidate for experiments - except really wild ideas that are too risky to try on greens in play. Do not use nurseries for experiments - results probably will not interpret into useful management decisions for the rest of the course in play.

Measurements

There are many factors that will influence the outcome of an experiment and only a few of which you will be able to control. The accuracy and precision with which products and practices are applied to the turf is one area where cutting corners may result in wasted time. The more care taken in carefully making measurements and calibration the more likely the results will be repeatable.

You will have to accurately measure time using a stop watch, distance using a tape measure, volumes using graduated cylinders, syringes or pipets, or precision flow meters, and weights using balances that can measure within 1 - 5% of the desired unit.

As a rule of thumb, try to measure all components with an accuracy of 1%. That means to measure 1 gram of a product the balance will have to have accuracy of 0.01 g. A standard triple beam balance will provide this level of accuracy for about $150. Volume measurements can be carried out using a variety of instruments from disposable pipets with accuracy down to 0.01 ml for small volumes

Equipment Costs and Your Time

There are a variety of sources for equipment to help apply products. Your existing equipment is the first place to start. However, if you are interested in small plot applications, Table 1 provides a list of suppliers and recommended items to assist in your efforts. Don't be fooled by the relatively low cost of the equipment needed to conduct testing programs. The investment in your time during experiment design, execution, observation and summary are far more costly than any equipment that you might purchase. For that reason, a carefully designed experiment is one that will provide the greatest benefit at the least cost.

Cost being your time and efforts. Your golf course turf quality will benefit and your budget may drop but be sure that you can afford the time needed to complete an experiment before you get started. And, as a rule of thumb, if you think it will take half an hour to calibrate your sprayer, allot twice that time. For some strange and perverted reason, experiments always take at least twice as long as you think they will take when you are sitting at your desk drafting up the objectives and materials and methods.

It's the law

Remember, it is illegal to use any pesticide that is not properly labeled, stored, and handled according the its label. This extends to the use of labeled products on pests or application to sites that are not explicitly listed on the product label. A research authorization (RA) must be obtained from the California Department of Pesticide (DPR) Regulation and the County Agricultural Commissioner must be notified prior to application of any product to a site or for control of a pest that is not listed on the product label. In addition, research conducted under a research authorization will require that a qualified applicator certificate holder be certified for demonstration and research applications. Stick to experiments with labeled products or obtain the proper permits and certificates before conducting trials with products outside the constraints of the products label - its the law.

References:

Camper, N.D. ed., 1986. Research methods in weed science. Southern Weed Science Society, Champaign. 486 pp.

Glinski, D.S., Mills, H.A., Karnok, K.J., and Carrow, R.N. 1990. Nitrogen form influences root growth of sodded creeping bentgrass. HortScience 25:932-933.

Hickey, K.D., 1986. Methods for evaluating pesticides for control of plant pathogens. APS Press, St. Paul. 312 pp.

Little, T.M., Hills, F.J., 1978. Agricultural experimentation. John Wiley and Sons, NY. 350 pp.

Table 1. Commonly used equipment for use in product testing. Products can include fertilizers, fungicides, herbicides, insecticides, nematicides, biostimulants, adjuvants, wetting agents, etc. Prices are ballpark estimates for each item to provide a rough idea of the relatively low cost of equipment needed to test products on-site.

Source	Description	Cat. No.	Quantity	Price/Quantity
A.M. Leonard				
800-433-0633	36"Gandy	36H12	1	252.62
Cole Parmer				
800-323-4340	150 g Scale	H-11300-16	1	125.00
	5000 g scale	H-1100-3-20	1	111.00
	Container for 5000 g scale	H-11003-60	1	10.00
	Graduated cylinder 500 ml	H-6137-90	2	15.00
	Pipet pump	H-06221-03	1	21.00
	Serological pipets 1.0 ml	H-13000-06	1,000	146.00
	Serological pipets 10.0 ml	H-13000-36	500	170.00
	Electrical conductivity meter, TDSTestr 4	H-19800-30	1	51.95
	Calibration solution for EC meter (500 ml)	H-01482-70	1	14.95
R&D Sprayers				
318-942-1001	Plot sprayer for liquids	Model AS	1	604.50