Iowa Commercial Pesticide Applicator Manual

Category

10

Demonstration and Research

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Demonstration and Research

Category 10

Prepared by Noelle Baker, special project consultant; Laura Sweets, former Iowa State University extension plant pathologist; Brent Pringnitz, extension program specialist in Agronomy; and Joyce Hornstein, extension program specialist in Entomology; graphics by Rex Heer; design layout by Dennis Melchert and Beth Kroeschell; and edited by Julie Todd, extension program specialist in Entomology.

This manual has been developed for individuals wishing to become certified in commercial pesticide applicator Category 10, Demonstration and Research. It contains specific information that an individual must know before becoming certified in Category 10. This manual has been designed to supplement the general information contained in the *Iowa Core Manual* (IC-445) and should not be used for certification preparation without referring to the *Iowa Core Manual*.

Contents

Introduction

This manual is intended to inform individuals of issues pertinent to the design, implementation, and evaluation of demonstrations or experiments that involve pesticides. Pesticide–organism interactions, interactions of the pesticide with the environment, and integrated pest management (IPM) are important topics that will be covered in this manual. Because there has been an increasing interest in on-farm demonstration and research, and the differences between demonstration and research, sections have been included in this manual that address these topics. The manual also addresses important design and safety considerations inherent in carrying out a successful demonstration or experiment.

Individuals in field demonstration and research pest control not only provide and disseminate information on pest control but also serve as examples for other applicators. Therefore, they should be particularly knowledgeable in methods of pest control, and they should demonstrate competence in the safe and effective use of pesticides.

They also must understand pesticide–organism interactions and recognize the importance of integrating pesticide use with other control measures in effective pest management programs. For example, cultivation often is needed to supplement the benefits of herbicides, and crop rotation helps to reduce the natural increase of many insects and disease-causing organisms, thereby decreasing the need for higher levels of pesticide application.

Demonstration and research pest control requires people who can:

- demonstrate to the public the proper use and techniques of applying restricted use pesticides or supervise such demonstrations, and
- conduct field research with pesticides.

The first group of people includes Cooperative Extension personnel, vocational agriculture instructors, community college agriculture instructors, industry representatives, and others who demonstrate effective pest control practices. The second group includes Iowa State University, community colleges, and other research and educational institutions; state, federal, and industry researchers; and others who conduct research in the field.

Pesticide–organism interactions

The beneficial and the harmful effects of pesticides are determined by pesticide–organism interactions or how pesticides and organisms react to each other. To do its job, a pesticide must (1) penetrate an organism, (2) move or be transported to a site of action, and (3) once there, disrupt or alter a vital function. The manner in which the pesticide affects a vital function is called its mode of action. Penetration, transport, and mode of action involve pesticide–organism interactions. Pesticide–organism interactions also are involved in the metabolism, accumulation, elimination, and detoxification of pesticides by a plant or animal.

Selectivity and the development of pesticide resistance are often caused by differences in pesticide–organism interactions. Selectivity is the ability of a pesticide to kill or otherwise alter one organism and not another. Resistance is the inherent ability of a pest to sustain less damage from pesticide application than other individuals of that species under comparable environmental conditions. An example of resistance to pesticides worldwide is in insects and mites. In the early 1990s, more than 500 species of arthropods were known to be resistant to insecticides. Pesticide resistance is not limited to arthropods; there are at least 200 species of fungi, 213 species of weeds, and several species of nematodes and rodents also resistant to one or more pesticides. Common waterhemp with resistance to acetolactate synthase-inhibiting (ALS-inhibiting) herbicides is common in the Midwest. Resistance often develops in pest populations that have been frequently treated with a single pesticide. Development of resistance in pest populations may sometimes be averted or delayed by reducing the number of treatments and alternating the type of pesticides used.

Penetration

The speed and extent of penetration depend on the permeability of an organism to the specific pesticide. This permeability differs significantly among plants and animals and even among different tissues of the same organism. In animals, tissues of the respiratory and digestive systems are usually much more permeable than the skin. In plants, the chemical and physical relationship between the leaf surface and the herbicide influences the rate and amount of uptake. Air temperature and relative humidity, plant size and age, and herbicide additives also affect penetration and uptake.

Transport

The movement of a pesticide from the place where it entered an organism to its site of action involves the motility of the pesticide molecules and the efficiency of the transporting mechanism of the plant or animal, i.e., how quickly the pesticide moves through the plant or animal’s system. Systemic herbicides must move through the plant to areas of interaction. Other herbicides are nonmobile in the plant and only affect the area in which they come in direct contact.

Mode of action

A pesticide performs its main function only after it reaches action sites within an organism. These sites are usually the protoplasm of living cells and often particular kinds of cells. For example, the cells targeted by organophosphate insecticides are the nerve cells. Atrazine affects the photosynthetic process in the chloroplasts of susceptible plant cells.

Pesticides kill or otherwise alter an organism by disrupting or interfering with some vital physiological function. This is called the pesticide’s mode of action. The mode of action of organophosphate insecticides (e.g., methyl parathion, malathion, Thimet®) is the inhibition of the breakdown of acetylcholine by cholinesterase, an enzyme that is essential in regulating the proper functioning of the nervous system. When acetylcholine accumulates, muscles and glands become overactive because of excessive stimulation of the nerve cells. Some herbicides act as plant growth regulators, speeding up or slowing down cell growth and reproduction; other herbicides act as desiccants, defoliants, or antitranspirants. One major class of herbicides, the ALS inhibitors, blocks the synthesis of critical amino acids within the plant. Fungicides may act as enzyme poisons and spore germination inhibitors.

Metabolism

Metabolism is the process by which a pesticide, or other chemical, is changed into one or more different chemicals within a living organism. The metabolic product, or metabolite, may be either more toxic or less toxic than the original pesticide ingredient. For example, corn is tolerant to triazine herbicides because it quickly deactivates these chemicals by binding them to other plant chemicals. Some pesticides are effective only after they have been metabolized to a lethal compound by an organism. Given enough time, an organism may be able to metabolize certain pesticides to their nontoxic metabolites. Survival may depend on whether or not the organism can metabolize the pesticide into nontoxic metabolites before the toxic activity is complete or irreversible.

Accumulation, elimination, and detoxification

Pesticide chemicals and their metabolites may be stored or accumulated within an organism or be eliminated as waste. If the level of exposure to most accumulated pesticides remains constant, an equilibrium between storage, metabolism, and elimination is reached, and the concentration of the pesticide and its metabolites remains constant within an organism. If the level of exposure is changed, the concentration within an organism correspondingly increases or decreases.

Because pesticide residues may accumulate within organisms, special precautions in harvest or slaughter must be observed with the treated commodities. Grazing, harvest, slaughter restrictions, and freshening intervals provide the necessary time for metabolites to be detoxified or eliminated before safe consumption of the treated product is allowed.

Biodegradation

Pesticides in the environment can be affected by:

- soil organic matter,
- soil pH,
- soil texture,
- ultraviolet light,
- soil microorganisms,
- soil moisture,
- temperature, and
- humidity.

These factors not only affect the efficacy of a pesticide but also determine the manner and rate that it is metabolized. Biodegradation is simply metabolism, but it more specifically refers to the decomposition of pesticide residues in the environment by bacteria and other microorganisms that use the residues as nutrient sources.

Biological magnification

Biological magnification is the tendency for certain pesticides to progressively become more concentrated in each type of organism when moving from the bottom to the top organism within a food chain. Biological magnification was believed partly responsible for the deaths and reproductive failures among predatory animals, especially hawk-like birds, eagles, and brown pelicans. Perhaps the most familiar example of reproductive effects of pesticides on nontarget organisms is the eggshell thinning in birds that was caused by certain chlorinated hydrocarbon insecticides such as DDT.

This eggshell thinning may have been initiated by a chain of events beginning when invertebrates that consumed plants with DDT residues were, in turn, eaten by rodents, reptiles, amphibians, fish, and insectivores, further concentrating the residues in their fat tissues. These predators were eaten by top predators in the food chain that then received yet higher insecticide concentrations. Fortunately, the chlorinated hydrocarbons have been banned for a number of years, and such biomagnification problems have reversed themselves. Top predators are again increasing in number. Recently, the bald eagle was removed from the endangered species list because the reproductive capacity of the population is rising. Thus, an awareness of such pesticide–organism interactions is important when working with certain pesticides.

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Integrated pest management

Integrated pest management (IPM) is the carefully managed use of a variety of pest control methods, such as natural pest enemies, crop rotations, and judicious pesticide use, to achieve economical and beneficial results with the least harm to the environment and to public health. Integrated pest management can be more effectively accomplished if the agricultural crop or other site of a pest problem is considered in its entirety and not merely as an arena in which to battle a pest. Past, present, and future conditions or practices tremendously affect the size of pest populations, the choice of pest control methods, and the degree of pest control achieved.

It should be recognized that any pest control practice, including the application of pesticides, will have effects other than the intended one(s). Such side effects may be good or bad, gross or slight, short-lived or long-lived, local or distant, obvious or nebulous. The demonstrator and researcher should be ever observant for these side effects and consider them in interpreting, reporting, demonstrating, and recommending pest control practices. Integrated pest management implies selecting those pest control measures that maximize beneficial effects and minimize harmful ones. Individual elements or control measures within the IPM program should be selected, used in the proper sequence, and timed to be compatible with each other and with other cultural or maintenance practices. Neither pesticides nor any other individual control measure should be overused to the extent that it loses its effectiveness, interferes with the effectiveness of other control measures, or adversely affects humans, other nontarget organisms, or the environment.

Pesticides are probably more subject to being overused or misused than other pest control methods. Such overuse or misuse may not only result in unnecessary harm or hazard to people and the environment but also may result in poor pest control or an even higher incidence of pest attack.

Furthermore, improper use of pesticides may result in resurgence of target pest populations or population explosions among secondary pests or nontarget pests because of the elimination of their natural enemies. Parasite and predator populations may survive an improper pesticide application but be decimated by starvation if their hosts and prey are killed off.

In certain instances, an organism may not be an important pest simply because competition from another organism keeps its population size below an economically damaging level. Such an organism becomes a pest when its competitor is removed. If broadleaf weeds are selectively killed by a herbicide, grassy weeds usually begin to thrive. Some pests that occur in crops late in the season are pests because the crop has been protected from competitors.

In some instances, a pest may be supporting another organism that becomes a pest when its host is controlled. Weeds and grasses may harbor insects such as stalk borers and armyworms that move to corn when their weed hosts are destroyed.

As a certified applicator in demonstration and research pest control, you must be ever mindful of the complexity of the environment in which pest control is practiced. Biological processes, climate, topography, various physical and chemical characteristics, maintenance or cultural practices, and use patterns are so interrelated that it is extremely difficult to adequately predict the effects that a pesticide may have on the ecosystem. You must be constantly alert and thoughtful in developing, recommending, and demonstrating pest control practices.

Setting up a demonstration or experiment

Good demonstrations and research experiments can be of great value; poor demonstrations and experiments can be worthless or even misleading. In deciding whether demonstration or research is appropriate, project planners need to keep in mind for whom the work is being done and what would convince that particular audience. The difference lies in the purposes of the activities: demonstrations seek to communicate and convince, whereas research seeks to answer a question. Research involves collecting data from experiments (consisting of treatments and controls) that are replicated and whose treatments are randomized. Demonstrations do not have to be replicated nor do they need to have controls; thus, they are **not** valid experiments. They also do not sample the variation within the test area. Such trials are not acceptable for publication of data or sales promotion but may be valuable to demonstrate an idea or management option.

Demonstration

Demonstrations must be visually convincing, but they do not necessarily include data collection or analysis. They are usually at one site, short-term, and unreplicated. For these reasons, demonstrations tend to be easier and less expensive to conduct than research. They can stimulate farmers to think about different management systems as well as convey simple recommendations. The results of demonstrations are of more restricted use than those of research because there is no way to measure their limits of confidence. Demonstrations are usually one of two types or a combination of the two: method demonstrations or result demonstrations. Method demonstrations show how to do something, e.g., how to calibrate a sprayer, tank mix difficult mixtures, or incorporate a herbicide properly into the soil. Result demonstrations show, by example, what happens with the practical application of new information or show principles or comparisons that support a practice or recommendation. Observations and notes should be taken throughout the season, particularly on unexpected developments. Field meetings are generally held to show the results. An effective result demonstration requires (1) a clear-cut and simple objective, (2) a genuinely interested cooperator who is respected in his or her area, and (3) a uniform field site (e.g., no dead furrows, old building sites, dry or wet areas, etc.) that is easily accessible.

Research

Research involves a systematic method designed to discover new facts or principles. Most research is conducted by using the following sequence of steps:

- formulating a hypothesis—a suggested solution or explanation,
- designing an experiment to **objectively** test the hypothesis,
- collecting data,
- interpreting data, and
- accepting, rejecting, or altering the original hypothesis.

A well-thought-out experiment should be simple, precise, and contain no systematic error (e.g., all of the plots receiving one treatment should not differ systematically from the plots receiving another treatment). The researcher should follow the scientific method meticulously when designing an experiment; however, he or she must realize that no answer is absolute and, therefore, all generalizations drawn from an experiment should be made with care.

Experimental error and bias are inherent in any experiment; therefore, a primary goal of the researcher is to reduce these influences to a minimum. Good experimental technique goes a long way toward minimizing bias and error. Every effort should be made to:

- apply all treatments uniformly,
- measure treatment effects in an unbiased way,
- prevent gross errors, and
- control external influences so that all treatments are affected equally.

Selecting materials

In most applied research, it is important to use materials in the experiment that will be involved in the actual crop or livestock production. For example, a comparison between the efficacy of a preplant-incorporated herbicide and a postemergence herbicide would not be advised. If treatment differences were found, it would be impossible to determine if one herbicide was actually superior to the other, or if, for example, the weather conditions favored the time of application (preplant incorporated versus postemergence). Before conducting a field experiment with pesticides, it is best to prepare a statement that answers the following questions:

- What are the objectives?
- What is the experimental design? How are the treatments and plots arranged?
- What variables exist within either the experiment or the plot area? Are

there soil, varietal, or breed differences?
- How many replications are needed?
- What is the sample unit and sampling procedure?
- How will the data be analyzed?
- How will the results of the experiment be used?

Definitions

Individuals should be familiar with the following terms to properly set up demonstration or research pest control work.

Bias. A manipulation of an experiment so that results do not accurately reflect the effect of a treatment.

Block. A group of experimental units or plots in which each treatment occurs the same number of times.

Check or **Control**. The experimental units or plots to which treatments are not applied.

Demonstrational experiment. An unreplicated trial comparing a new treatment or treatments with a standard.

Experimental error. An inconsistency inherent in an experiment that may affect results.

Experimental unit. The unit of material to which one application of a treatment is applied. This unit may be a plot, an individual plant in a pot, a single animal, or a pen of animals. Do not confuse an experimental unit with a sample (see next column).

Randomization. The process of arranging treatments by purely objective methods, e.g., drawing numbers out of a hat.

Replication. When a treatment appears more than once in an experiment.

Sample. Representative unit(s) taken from a population, e.g., the number of velvetleaf plants or corn borers counted in each plot.

Treatment. The factor being tested in an experiment, e.g., type of herbicide or fungicide.

Trial. An experiment: a group of plots to which treatments have been applied.

Replication and randomization

Replication and randomization are basic components of valid research experiments. They function to decrease experimental error and provide validity to the data obtained from the experiment. Both components are described in more detail below.

Replication. Apply each treatment to more than one experimental unit in each experiment. For example, 12 plots would be needed for an experiment that tested three different herbicide treatments and a control, if each was replicated three times. Many field experiments are repeated over a number of years or at several different locations. These also can be considered broad forms of replication.

By replicating an experiment, researchers are able to estimate the amount of experimental error in the study and improve the precision of the results. The number of replications required in a particular experiment depends upon the magnitude of the differences the researcher wishes to detect and the variability of the data. Careful consideration of the number of replications at the beginning of the experiment can save much frustration later.

Replication by location is a design technique in which each farm (or location) is treated as one replication. Several farms (or locations) together are analyzed as one experiment.

Randomization. The assignment of treatments to plots in a purely objective (random) manner is called randomization. Every treatment should have an equal chance of being assigned to any experimental unit. This ensures a valid and unbiased estimate of the experimental error and treatment differences.

Many factors might affect the outcome of experimental field work—soil type, drainage, compaction, erosion, pest infestation, temperature variation, and so on. Such factors may change with time and with location in a field. Thus, the researcher or individual involved in pest control demonstration work must be constantly alert in selecting field areas for plots. When randomizing plots, avoid systematic arrangements such as regularly alternating two treatments or repeating several treatments in the same order. Avoid selecting a group of numbers that "look as though they ought to be random." Randomization can be achieved by using methods such as tossing a coin, drawing cards or numbers, using a table of random numbers, or having a calculator or computer that can serve as a random number generator.

Experimental design

Designing an experiment is an extremely important process because errors made in the design can invalidate the results of the entire experiment. The most able statistician cannot validate conclusions from an improperly designed experiment. It is generally best to avoid experiments or demonstrations that involve elaborate designs. Knowing your financial, land-area and field-resource limits can help in planning a successful experiment. If you have questions about your experimental design or method, seek assistance from a qualified statistician before starting your research.

Completely randomized

The completely randomized design is the most simple design (Fig. 1). It is set up by assigning treatments and controls at random to a previously determined set of experimental units. Any number of treatments may be tested in this design. It is desirable to assign the same number of experimental units to each treatment and control, but it is not essential.

When plots are laid out within a field, the number of plots is determined by multiplying the combined number of treatments and controls by the number of replications desired, e.g., 17 herbicides + 1 control = 18 treatments $\times$ 3 replications = 54 plots. The treatments are assigned to the plots at random.

The advantages of the completely randomized design are that it is flexible and simple. However, estimating experimental error with this design may be less precise than with other designs. The completely randomized design is not usually the most efficient design for research in field crops and may be better suited for trials with livestock.

Randomized complete block

The randomized complete block design (Fig. 2) is used to account for natural variability among treatments that would otherwise obscure treatment differences. In this design, the treatments are assigned at random to a group of plots called a block; thus, a block is a grouping of a single occurrence of all treatments. Because adjacent plots usually yield more alike or have more similar disease or pest infestations or similar fertility than those separated by some distance, the block is kept as compact as possible. This is accomplished by placing the plots, usually long and narrow, close together. The number of treatments also should be as small as possible. Note that each treatment occurs only once in each block. Treatments are assigned at random to plots within each block, with a separate randomization made for each block.

Split-plot

The split-plot design is useful with factorial experiments that evaluate both pesticide performance and crop management practices (e.g., tillage, row spacing, crop variety). An example would be an experiment to evaluate the effectiveness of three herbicide treatments in no-till (nt) and conventional tillage (ct) (Fig. 3). To simplify the experiment, tillage treatments are established as whole plots. Each whole plot is divided into four subplots and the herbicide treatments (three herbicide treatments plus a control) are randomized within each whole plot. The advantage of this design is that it simplifies establishing experiments where large equipment is used. The disadvantage is a loss in precision in determining differences among the whole-plot treatments.

Split-block

A variation of the split-plot design is the split-block design where the subunit treatments are applied in strips across an entire replication of main plot treatments (Fig. 4). This arrangement often facilitates physical operations concerning the subunits but sacrifices precision in comparing the main effects of the subunit effect.

Control or check plots

The experimental units or plots to which the treatment is not given are called the controls or checks. **Inclusion of control plots is strongly recommended in all statistically sound experimental field work**. Failure to include control plots or the incorporation of inadequate control plots provides only questionable results that are unacceptable for publication and sales promotion. Check plot selection should be made with the same objectivity as that of other plots. The same variables that may affect treatment plots also may affect control plots. Control plots should not be arbitrarily located near a fencerow, head-land, gate, or simply in the middle or side of a field. Likewise, control animals should not be arbitrarily selected but should represent a random sample of the test population.

On-farm experimental plots

Design decisions, such as the number of treatments and replications or the size of the plots, must always consider what farmers are willing to do and what they can do within the constraints of operating a private farm. Sometimes this means making compromises, lest the entire

Figure 1. Completely randomized design with three replications, three treatments (A, B, and C), and one untreated control (D).

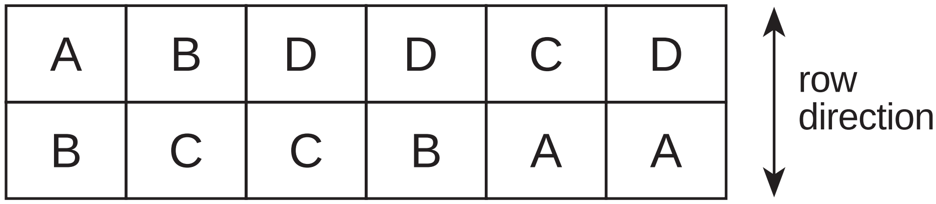


Figure 2. Randomized complete block design with three treatments (A, B, and C) and one untreated control (D) replicated four times.

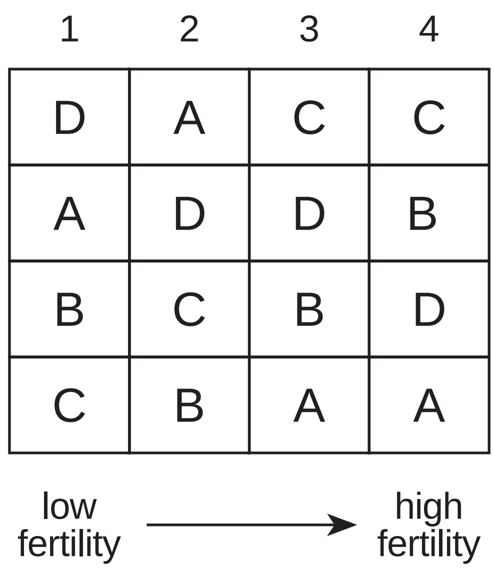


Figure 3. Randomized split-plot design with three replications. Tillage treatments (no-till [nt] and conventional tillage [ct]) are the whole-plot treatments and herbicide treatments (1–4) are subplot treatments.

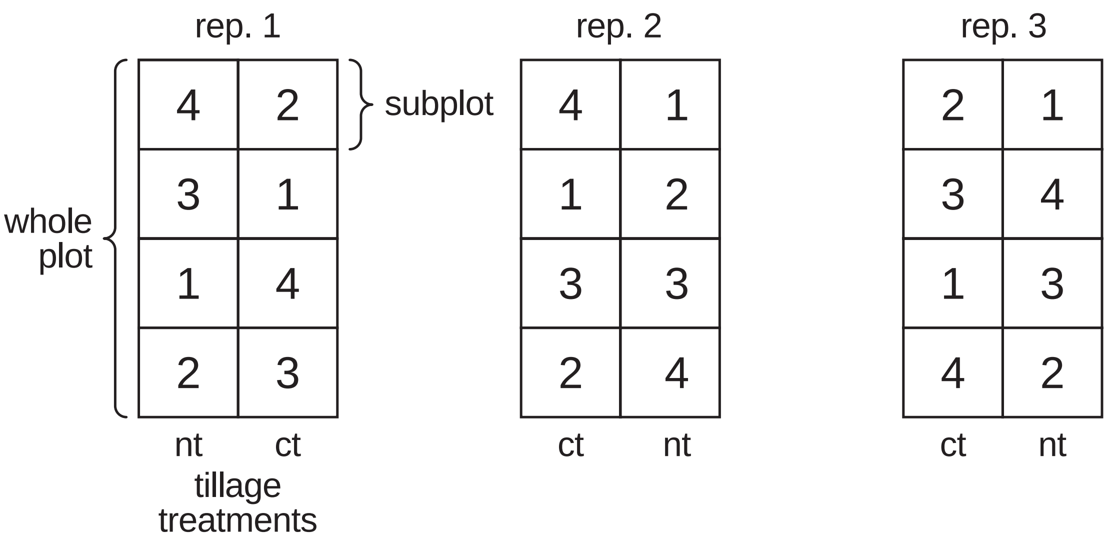
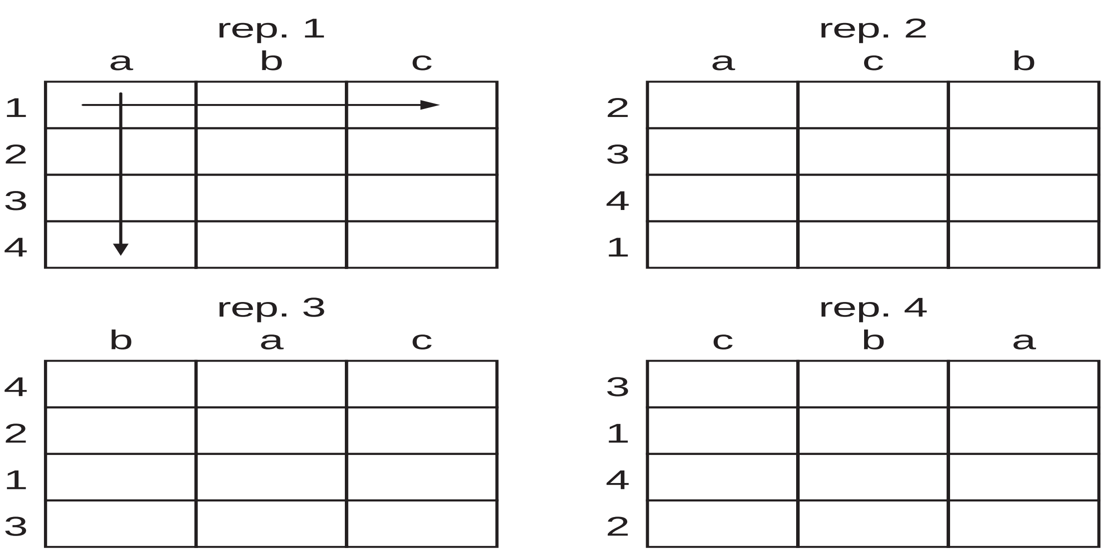


Figure 4. Split-block design with four replications, three main treatments (a, b, c) of corn planting dates, and four subplots (1, 2, 3, 4) of fertilizer treatments. Fertilizer treatments are continued across the main treatments to facilitate application with large equipment. This design differs from the split-plot design in which subplots are randomized within each main treatment.



study fail. Farmers favor on-farm trials that use standard machinery and require little extra time to implement and maintain.

One on-farm method that has become acceptable to a large number of producers involves using long, narrow strip plots. The strip plots are arranged in a randomized complete block design (Fig. 2) with some modifications made to accommodate the situation on a private farm.

Producers can readily use the randomized complete block design with only a few limitations. No more than five treatments should be tested in on-farm strip plots. Examples of treatments might include four soybean varieties, five rates of fertilizer, or three tillage methods. There should be five to seven replications of each treatment.

Fig. 5 shows an example of a field experiment using a randomized complete block design for testing three weed control treatments (A, B, C) and an untreated control (D). Five replications of each method are planned, thus, there are five blocks.

The blocks are arranged to allow all treatments within a block to be exposed to similar conditions, such as slope, soil type, and previous cropping history. Experiments conducted on a hillside should have the strips running perpendicular to the predominant slope of the test area or along the contours of the land. The blocks of strips thus account for much of the field variation due to differences in moisture and other factors that are affected by slope.

Within each block the treatments are randomly assigned to the strip plots. The strip plots can be one width (or two widths) of a producer's planting or harvesting equipment. In many cases this width is six or eight rows wide. Strip-plot length can be anywhere from 100 feet to half a mile. Experiments using 0.5-mile-long strips generally provide good results.

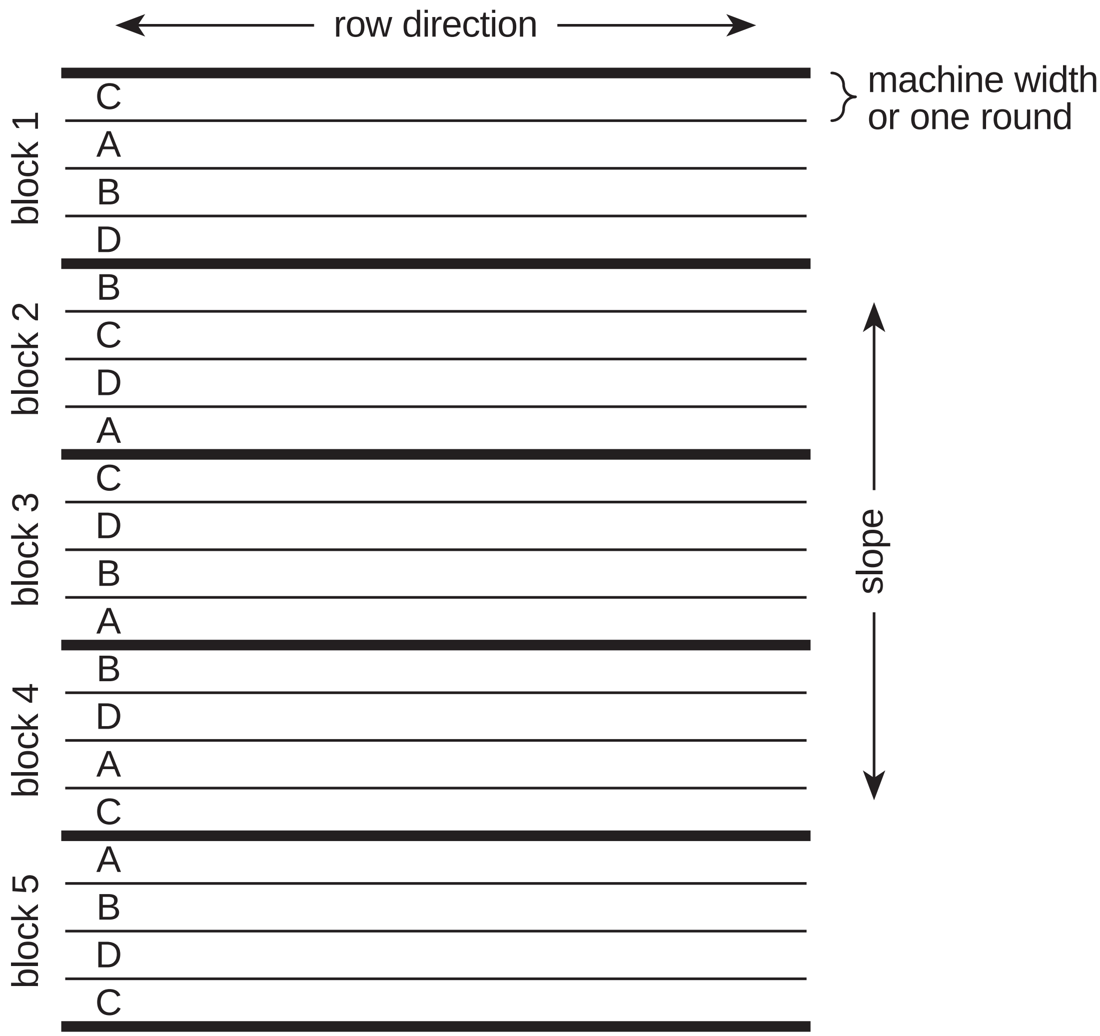
All strips are managed identically throughout the growing season except for the treatments being tested. For example, if a trial is testing different methods of weed control, all strips should receive the same primary tillage, seedbed preparation, fertilizer application, insect control, and so on. The only difference in management over the entire test area in this trial would be the weed control treatment used on each individual strip plot.

On-farm research

During the past few years there has been an increased interest in on-farm research. A well-thought-out on-farm experiment can complement research conducted on a research station. However, the experiment station is usually a more appropriate place to screen riskier alternatives, experiments that may make a field look bad, or experiments that could leave farmers with a lingering problem, such as weeds.

Acceptance of an on-farm research project will be enhanced if its purpose is clearly identified, so that it is judged by appropriate standards. In particular, the

Figure 5. On-farm experiment with three treatments (A, B, C) and a control (D) replicated five times by using the randomized complete block design.



distinction between demonstration and research must be kept clear.

The researcher may decide to conduct an experiment on-farm if the experiment itself requires a private farm and operator, or the farm location offers physical conditions that are not found on-station (e.g., a particular soil type, climate, or pest infestation). Other factors may influence any particular researcher to conduct an experiment on-farm rather than on-station. In many instances, on-farm research is more credible and accessible to farmers, particularly if it is done with large, machine-harvested plots. The researcher should keep in mind that the two sites (on-farm vs. on-station) require different intensiveness in monitoring the experimental plots.

It is important to make farmers' and researchers' respective responsibilities very clear. It is not fair to expect extra work from farmers or meticulous station-type data collection during busy seasons. The researchers must adapt the experiment to what they judge each farmer can conveniently do. Once a cooperator has been selected, efforts should be made to compensate him or her fairly for time and effort in a manner appropriate to each individual situation.

Equipment calibration

Correct calibration and accurate measuring and mixing of pesticides are extremely important in demonstration and research pest control work. Although the hazards of application may be reduced and the chances of nontarget pollution minimized in small-plot vs. large-plot work, the probability of misapplying the correct rate of pesticide in small-plot work is generally increased. Small errors in measuring the experimental material, for example, may cause over- or under-dosing of the treatment plot. The addition of 2 fluid ounces of a herbicide in a 100-gallon tank of water during mixing for general field application may not necessarily be significant. However, this small amount added to 2 quarts of water in small-plot research can result in highly inaccurate results.

Small-plot experiments often demand that the researcher work with measurements of grams, milliliters, or ounces rather than pints or pounds. Rough estimates or "rounding off" in the measurement of pesticides for demonstration and research is not an acceptable practice.

Liquid measurements should be made with graduated cylinders or pipettes. Safety pipette fillers or propipettes should be used with pipettes to avoid getting the pesticide into the researcher's mouth.

Dry materials should be measured on properly adjusted scales that provide measurements in milligrams, grams, or ounces. Conversion tables and sample problems are provided in Appendix I for reference.

Application techniques

A well-designed experiment can lose its value through careless techniques of treatment application and data sampling or collection. Listed below are some points to consider:

- Carefully label all plots or experimental units.
- Avoid nonuniform applications.
- Clean application equipment between treatments.
- Avoid unequal preparation, treatment, or maintenance of the check plots.
- Require one individual to make all treatments.

Sampling techniques

Even though the experiment has been properly designed, high-quality data can be obtained only by using a carefully planned and uniform sampling method. If the sample taken, whether of a pest population or pesticide residues, is not representative, the results are not valid and are of little value. Such data may lead to erroneous and misleading conclusions. Samples must be taken at random within the designated plot sample area.

A number of variables must be taken into account **before** a representative sample can be obtained. These variables include the source of the sample, the size and part of the commodity to be sampled, the method of application, and the purpose of the sampling.

For practical reasons, there is a limit to the number of samples that can be taken from a particular plot. Therefore, certain fundamental sampling methods must be followed. In general, the sample should represent the situation in the plot, and if for pesticide residues, reflect the level of residue on the crop as it reaches the final consumer. If the plots are small, it is desirable to avoid taking samples near the borders. Require one individual to take all samples. If more than one individual is involved, do not allow one person to sample all replications of one treatment. If possible, sample at the same time (hour, day) and do not pool or bulk samples initially.

Control plots are essential in any experiment. An alternate pesticide may be used when an absolute check (no treatment) is not possible. If sampling is to be for residues, consult a residue analyst so that consideration is given to possible contaminating or interacting substances. Borders of control plots should be avoided because of possible drift effects.

Recordkeeping

Accurate and complete records contribute to the success of an agricultural enterprise. Pesticide application records provide a permanent record of pesticide purchase dates, rates and names of pesticides applied, application dates, types of equipment used, weather conditions, and location of each pesticide application.

Complete pesticide application records are important when considering the economic value of accurate, properly timed pesticide applications; regulations regarding pesticide residues in soils; and the variability in susceptibility of different crops to certain pesticides. In addition, Iowa law requires that all commercial pesticide applicators keep records of pesticide applications for at least 3 years following the date of application.

Carry a pocket notebook with you and record information as it happens. Do not rely on your memory. Transfer this information to a permanent record sheet that is kept in a safe place. Further information on recordkeeping is contained in Appendix II.

Safety

Individuals involved in demonstration or research pest control are not exempt from following standard safety procedures and safety precautions that are listed on the pesticide label when:

- choosing and wearing personal protective equipment,
- measuring and mixing pesticides,
- calibrating equipment,
- training employees who will work in pesticide-treated areas,
- applying pesticides,
- cleaning equipment,
- disposing of pesticides, and
- maintaining safe storage of pesticides in their original containers.

Common sense dictates that the applicator practice good safety techniques when handling pesticides because some materials may be experimental or numbered compounds that are unfamiliar to the applicator.

The applicator is required to wear the personal protective equipment listed on the label. If the pesticide is an experimental product and no label is available, obtain the Material Safety Data Sheet (MSDS) from the manufacturer. The minimum safety equipment that must be **accessible** and **used** when working with such pesticides is:

- neoprene gloves,
- respirator,
- hat,
- long-sleeved shirt or jacket,
- coverall-type garment, and
- goggles or face shield.

A supply of water, soap, and towels must be available at the application site for cleansing or for emergency decontamination of individuals who have spilled pesticides on themselves.

Neither a small area treated nor a limited amount of pesticide used in demonstration and research work precludes following safe application procedures. Misuse of any pesticide could result in acute or chronic injury or even death to humans or nontarget plants and animals.

Before mixing and applying pesticides in research work, the investigator should read the entire label and the MSDS and be aware of:

- the acute oral and dermal toxicity of the compound (oral and dermal LD_{50}),
- inhalation toxicity (LC_{50}),
- special hazards,
- the required personal protective equipment,
- location of the nearest medical facility, and
- antidotes in case of poisoning.

Knowledge of these factors gives the researcher insight on the safe handling, application, and disposal procedures of experimental materials. Most importantly, knowing this information helps prevent serious injury to the researcher or applicator. See additional demonstration and research procedures in Appendix III.

Disposal

Excess pesticides used in demonstration and research pest control must be disposed of properly. Pesticides that can be legally applied to areas adjacent to the test plots can be disposed of in this manner. Carefully read and follow all directions for proper disposal listed on the label. Do not dump excess pesticides in or along field margins, fencerows, or grass waterways. Illegal amounts of residues, water contamination, nontarget plant injury, and wildlife kill may result.

Extra, unopened containers of concentrated pesticides should be returned to the manufacturer or dealer. Excess mixed pesticides should be collected at the application site and sealed in labeled containers for later disposal at an approved site. Proper disposal consists of calling:

- Environmental Health and Safety Program at 515-294-5359 for disposal information and instructions (if you are an Iowa State University employee), or
- Iowa Department of Natural Resources at 515-281-5859 for information about regional hazardous waste collection centers in Iowa.

Experimental-use permits

An experimental-use permit allows limited field testing of an unregistered pesticide or of a registered pesticide for an unapproved use. The permit allows limited field testing to gather data on efficacy and safety in support of application to register the pesticide or expand the label. Experimental-use permits facilitate developing new, less hazardous pesticides while providing sufficient regulatory control to protect human health and the environment. Permits are issued by the Environmental Protection Agency's Office of Pesticide Programs on a temporary basis. If the application of an experimental pesticide could result in any residue on or in food or feed, the Office of Pesticide Programs will set a temporary tolerance or safe residue level before issuing a permit.

Experimental-use permits **are not** required for pesticides being put through the following:

- laboratory or greenhouse tests,
- field tests of less than 10 acres,
- aquatic tests of not more than one surface-acre of water, or
- experimental animal tests.

All field crops treated with experimental pesticides must be destroyed or consumed by experimental animals unless a tolerance has been established.

No animals may be tested if they may be used in food or feed unless a tolerance or exemption from tolerance has been established. Waters that are involved or are affected by such tests cannot be used for irrigation, drinking water supplies, or body-contact recreation activities. Tests cannot be conducted in any waters that contain or affect fish, plants, or animals taken for recreation or commercial purposes and used for food or feed unless a tolerance or exemption has been established.

Pesticides under experimental-use permits cannot be sold or distributed to anyone other than the participants and must be used only at the designated application site in accordance with the terms and conditions of the permit.

Application for an experimental-use permit should be submitted to the Document Processing Desk (EUP), Office of Pesticide Programs (H7504C), U.S. Environmental Protection Agency, 401 M Street, S.W., Washington, DC 20460, at least 90 days prior to the intended date of shipment or use.

Some of the information necessary for submission to the Office of Pesticide Programs for application for an experimental-use permit is as follows:

- name and address of applicant;
- registration number of the product, if registered;
- purpose or objectives of the proposed testing, a description of the testing program, and designation of pest(s);
- amount of pesticide to be used; application rate and technique; number of acres, animals, or sites; and manner of supervision;
- complete name, address, and qualifications of all participants;
- name and address of all cooperators; and
- information on effects to target organism and phytotoxicity information.

Misuse of any pesticide under this permit may lead to civil or criminal penalties. The Office of Pesticide Programs may revoke a permit at any time if its terms are being violated, or if the testing threatens to damage the environment.

All pesticides shipped or used under an experimental-use permit must be labeled with directions and conditions for use as directed in the permit. These labeling directions and conditions must include normal labeling information plus:

- any limitations on entry of persons into treated acres,
- the prominent statement “For experimental use only,”
- the experimental-use permit number, and
- the statement “Not for resale.”

Appendix I—Calibration

Calibration abbreviations

gallon	=	gal
ounce	=	oz
fluid oz	=	fl oz
pint	=	pt
pound	=	lb
quart	=	qt
milliliter	=	ml
foot	=	ft
square foot	=	sq ft
inch	=	in.
mile	=	mi
miles per hour	=	mph
minute	=	min
second	=	sec
active ingredient	=	ai
gallons per acre	=	gpa
gallons per minute	=	gpm

Sample calibration problems

A. Useful information for calibration

1 acre	=	43,560 sq ft
1 mi	=	5,280 ft
1 lb	=	16 oz
1 gal	=	4 qt = 8 pt = 128 liquid oz = 3,785 ml
1 mph	=	88 ft/min = 1.47 ft/sec

B. Mixing liquid concentrate

To determine the number of gallons of concentrate to mix with water for spraying 1 acre, use the following equation:

$$\text{gal of concentrate} = \frac{\text{lb / acre of ai recommended}}{\text{lb of ai / gal (formulation)}}$$

Example: If the recommendation was 1.5 lb of atrazine per acre, and the purchased gallon of product contained 4 lb of active ingredient per gallon, the number of gallons of product needed per acre = 1.5 ÷ 4 = 0.375 gal = 3 pt.

C. Mixing dry pesticides

To determine the amount of dry pesticide to mix with water or the amount of granules to apply, use the following equation:

$$\text{lb needed / acre} = \frac{\text{lb / acre of ai recommended}}{\text{percent formulation}} \times 100$$

Example: If the recommendation was 4 lb ai / acre and the purchased pesticide granules contain 20% ai, then the amount (in pounds) of 20% pesticide needed per acre = 4 ÷ 20 × 100 = 20 lb.

D. Calibration of small spraying equipment

Small-plot equipment must be calibrated to deal with the precise applications required and to guarantee accurate results in research. Small sprayers can be calibrated by using the following method:

1. Based on the pesticide manufacturer's broadcast recommendations of gpa application rates, and on nozzle type for the specific situation, select a suitable spray tip size from the manufacturer's recommendations and from catalogs. Note information on various combinations of pressure, nozzle spacing, sprayer ground speed, spray angle, and the gpm or gpa delivered for the nozzle tip.

2. Select the ground speed based on what you consider to be a comfortable operating speed. A common speed is 3 mph for plot work. To determine accuracy of ground speed:

Sprayer ground speed

Speed in mph (miles per hour)	Time required in seconds to travel 100 feet
1	68
2	34
3	23
4	17
5	14

3. At this point, the nozzle type, tip size, angle, spacing, pressure, and sprayer speed that closely deliver the recommended gpa rate have been established. Now determine the **actual** spray delivery in gpm or gpa output by collecting the output from a nozzle over a timed period and by using one of the following formulas:

$$gpm = \frac{gpa \times mph \times W^*}{5{,}940} \qquad gpa = \frac{5{,}940 \times gpm \text{ (per nozzle)}}{mph \times W^*}$$

milliliters per minute ÷ 3,785 ml / gal = gpm

*W = spacing between nozzles in inches. If this is a single nozzle, W is the spray width in inches.

Note: Output can be collected for less than a minute.

Example: If 126 ml is collected in 10 sec, what is the output in ml / min? in gpm?

Answer: 126 ml ÷ 10 sec = 12.6 ml / sec × 60 sec = 756 ml / min
756 ml / min ÷ 3,785 ml / gal = 0.20 gpm

4. Sample calculations using gpm and gpa formulas

a. How many gallons per minute will need to be collected from one nozzle to attain the desired gallons per acre rate? How many milliliters need to be collected in 10 sec?

Given: 30-gpa rate, 3 mph, 20-inch nozzle spacing
Answer: $gpm = \frac{gpa \times mph \times W}{5{,}940}$ $gpm = \frac{30 \times 3 \times 20}{5{,}940} = 0.3$ gpm

0.3 gpm × 3,785 ÷ 6 = 189 ml in 10 sec

b. How many gpa will be delivered if you collect _____ gpm?

Given: 0.27 gpm collected from one nozzle, 3 mph, 20-inch spacing
Answer: $gpa = \frac{5{,}940 \times gpm}{W \quad mph \times}$ $\frac{5{,}940 \times 0.27}{3 \times 20} = 26.7$ gpa delivered

5. Final adjustments
Check all nozzles for output. Replace a nozzle if the amount delivered from any one on the boom varies more than 5% from the average output.

Slight adjustments in pressure or variation in ground speed can fine tune the output to the desired amount.

E. Calibration of large equipment: The "ounces-to-gallons" method[1]

Large application equipment, commonly used with on-farm research and demonstration work, can be easily and accurately calibrated with the following method. This method is designed to minimize the calculations and time required for calibration. The tools needed are: a measuring tape, a watch with second hand, and a measuring jar graduated in ounces.

1. Fill the sprayer tank with water.
2. Determine the nozzle spacing in inches and measure the appropriate distance in the field according to the following table:

Nozzle spacing (inches)	Travel distance (feet)
10	408
15	272
18	227
20	204
30	136
36	113
38	107
40	102

[1]From *Broadcast Sprayer Calibration*, Pm-817, Iowa State University Cooperative Extension (January 1982) and *Sprayer Calibration Pocket Card*, PAT 27, Iowa State University Extension (October 1996).

3. In the field, drive the designated distance at your normal spraying speed. Record the travel time in seconds.

4. Set the desired pressure on the sprayer. With the sprayer parked, collect the output from each nozzle for the recorded travel time. Record the output of each nozzle separately.

5. Calculate the average discharge rate of all nozzles in ounces. If any nozzles are more than 5% below or 5% above the average, replace those tips.

6. Ounces = gallons per acre

If the above gallonage is not reasonable for the product being applied, change the rate by:

adjusting the pressure, or
adjusting the travel speed, or
changing the nozzle size and recalibrate.

To use this method for directed or banding applications, use band width in place of nozzle spacing in the table on page 26.

F. Band applications of pesticides[2]

To determine the amount of pesticide to apply per acre when the band application is made for a specific row width but the actual row width is different, use the following equation.

$$\text{amount / acre for new row width} = \frac{\text{row width in recommendation}}{\text{row width used}} \times \text{recommended rate}$$

Example: If row width is changed from 40 to 30 inches and the recommendation for 40-inch rows is 1.5 lb of pesticide, the rate per acre for 30-inch rows would be:

$$\text{rate / acre} = \frac{\text{40-inch row}}{\text{30-inch row}} \times 1.5 \text{ lb} = 2 \text{ lb / acre}$$

The recommendation is in rate per acre. Determine the actual area covered by dividing the row width into the band application.

Example: Rows of crop are 40 inches wide. A band or strip application of 10 inches is being made. The portion of field that is sprayed can be determined by:

$$\text{area treated} = \frac{\text{10-inch band}}{\text{40-inch row}} = \frac{1}{4} \text{ or } 0.25$$

[2]From *Banding Herbicides for Row Crop Weed Management*, Pm-1393 (Revised, October 1990).

G. Calibration by using ounces per 1,000 ft of row

Determine the ounces (oz) needed for any length of row when recommendation is in oz / 1,000 ft.

$$\text{ounces needed} = \frac{\text{distance pesticide collected}}{\text{1,000 ft}} \times \text{recommended rate in oz / 1,000 ft}$$

Example: Four ounces of insecticide must be collected from each planter unit if the distance collected is 500 ft and the recommended rate is 8 oz / 1,000 ft of row.

4 oz = 500 ft / 1,000 ft × 8 oz

$$\text{ounces needed} = \frac{\text{500 ft}}{\text{1,000 ft}} \times 8 \text{ oz} = 4 \text{ oz}$$

Convert ounces per 1,000 ft of row to determine pounds needed per acre as follows:

$$\text{lb / acre} = \frac{\text{recommended oz / 1,000 ft of row}}{\text{1,000 ft of row}} \times \frac{\text{linear feet of row in 1 acre}}{\text{16 oz}}$$

Example: Recommendation is 9 oz / 1,000 ft of row. Row spacing is 30 in. or 17,424 ft / acre.

$$\text{lb / acre} = \frac{\text{9 oz}}{\text{1,000 ft of row}} \times \frac{\text{17,424 ft / acre}}{\text{16 oz}} = \text{9.8 lb}$$

H. Calibration by driving over a set distance
Determine the discharge rate per acre when equipment is driven a known distance as follows:

$$\text{amount / acre} = \frac{\text{amount collected}}{\text{distance traveled (ft)}} \times \frac{\text{sq ft / acre}}{\text{width of coverage (ft)}}$$

Appendix II—Recordkeeping

Commercial and public applicators must comply with Federal and State pesticide recordkeeping requirements. Maintaining accurate pesticide application records is important for safe and effective pest management. The records must be kept for 3 years following the date of application. Record the following information for all applications of restricted use pesticides:

- Brand or product name of the restricted use pesticide;
- EPA registration number of the restricted use pesticide (from the label);
- Total amount of the restricted use pesticide applied (the product, not the active ingredient);
- Location of the application according to one of the following: (1) county, range, township, and section number system; (2) personal identification system using maps and / or a written description that accurately and clearly identifies the location of the restricted use pesticide application; (3) an identification system used by a U.S. Department of Agriculture agency, such as map systems used by the Natural Resources Conservation Service (NRCS); or (4) legal property description;
- Size of the area treated (spot treatments have fewer information requirements);
- Crop, commodity, stored product, or site to which the restricted use pesticide was applied;
- Month, day, and year the restricted use pesticide was applied;
- Name and certification number of the applicator who applied the restricted use pesticide; and
- Temperature and the direction and estimated wind velocity at the time of application to any outdoor area.

In addition, applicators may find it useful to keep records on the following:

- Crop and variety planted or animals treated;
- Crop history, including planting date and developmental stage;
- Percent active ingredient, type of formulation, manufacturer, and purchase date;
- Calibration of equipment, including nozzle size, and pressure and throttle settings;
- Weather conditions, soil moisture conditions, and relative humidity;
- Total cost of the application;
- Treatment time of animals, and their average weight; and
- Application results.

Appendix III—Demonstration and research safety procedures

Prior to conducting demonstrations or research where pesticides, drugs, and other chemicals will be used, the following precautions should be taken to protect the investigator, workers on the project, animals involved, and the environment where the work will take place:

- Obtain toxicological data to be satisfied that the health of the applicator and any other people working in the area will not be jeopardized if the compound is used in the prescribed manner. One source of this information is the Material Safety Data Sheet (MSDS) that may be obtained from the manufacturer. Make sure you ask questions if the toxicological or safety information is not complete or you do not understand the instructions.
- Carefully read and understand the label of the pesticide or chemical you are using. In the case of pesticides, "the label is the law" and you must follow the label and any supplemental label materials to use the product in a legal manner according to the United States Environmental Protection Agency (USEPA). Make sure you follow the provisions of the Worker Protection Standard[1] as it applies to pesticides used in agricultural research as well as other general applications.
- Make sure you wear the personal protective equipment listed on the pesticide label for each different operation such as mixing, application, and reentry into a treated area. You also must provide your workers with the correct personal protective equipment if they are reentering a treated area during the restricted entry interval (check the label for details).
- Obtain from the sponsor of the research or the producer of the chemical, drug, or pesticide, information on the method (acceptable to the USEPA) by which animals or plants that are treated with these compounds must be disposed of. Also obtain a statement as to who will accept responsibility for disposing of the commodity and providing compensation for it.
- Inform the owner of the commodity to which the compound will be applied of all possible dangers to him / her, the crop, or the test animals. Inform the owner of the method of disposal for the crop or test animal.
- Secure a simple, written statement outlining contributions and responsibilities of each party.

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[1] Complete information about the Worker Protection Standard can be found in *The Worker Protection Standard for Agricultural Pesticides—How to Comply*, EPA 735-B-93-001, July 1993, available from the U.S. Government Printing Office, Superintendant of Documents, Mail Stop: SSOP, Washington, DC 20402-9328.

Before Using Any Pesticide

STOP

READ THE LABEL

All pesticides can be harmful to health and environment if misused.

Read the label carefully and use only as directed.