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II — CHEMICAL APPLICATION EQUIPMENT

Chemical Application Equipment

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Introduction

Simply stated, the objective of a chemical application program can be summed up with a single sentence. *Put the right product on the right target at the right time.* To accomplish this objective, good management practices and proper equipment are necessary. In selecting agricultural chemical application equipment, follow these guiding principles:

1. Considering acreage, crops, and labor, select the equipment that will best fit your farming operation.
2. For medium to small farms, select smaller units. Large equipment is impractical on small farms with fields of irregular shape, leading to frequent breakdown and poor application.
3. Use separate spray equipment for certain types of weed-control chemicals to prevent accidental contamination and crop damage.
4. Remember that some chemical application equipment is designed for specific applications, and some components are not suitable for all jobs. For example, some spray nozzles recommended for insecticide application may not be suitable for herbicides.
5. Select a machine that is convenient to set up, hitch, and operate. Convenient features can help a busy operator complete an application on time.
6. Keep in mind that high-clearance, self-propelled sprayers often cannot be justified on small farms; consider hiring a custom operator if this type of machine is needed.
7. Use the proper pressure for spraying; avoid excessively high pressures. Check the chemical manufacturer's label for recommendations.
8. Check all adjustments for any type of application equipment carefully. Refer to your operator's manual for recommended settings. **Remember to CALIBRATE!**
9. Wear the proper protective clothing and use other recommended personal protective devices or practices when handling or using agricultural chemicals.

Types of Equipment

Dusters

Dusters are no longer widely used for field crops. Sprayers and granular applicators are generally preferred. However, small, hand-held dusters and backpack dusters are still quite popular for use in gardens and around the home.

When dusters are used for field crops, their operation must be carefully supervised. Keep the dust hopper, fan, fan cage, flexible air lines, and nozzles free of caked materials. Place nozzles directly over the row, only a few inches above the target. Pay particular attention to the condition and adjustment of the V-belt drive. Proper alignment and tension are essential to maintain the correct air volume and velocity as well as the proper discharge rate from the hopper. Canvas drapes may reduce drift in windy conditions. Attention to maintenance and operation can improve application and may reduce the amount of chemical that needs to be applied.

Small dusters for home or garden use are typically hand-held and hand-powered. Large dusters can be backpack units powered by small gasoline engines or battery-powered motors. They can hold from a few ounces to several pounds of material. The fan or air pump generates the necessary airflow to move the dust through the discharge tube to the nozzle. Aim the nozzle at the proper target and watch the application rate closely. It is easy to apply too much material in one small area, which can be hazardous.

Granular Applicators

Granular applicators are used for a wide range of jobs, from applying small volumes of pesticides at planting to applying fertilizer or lime using band or broadcast methods.

Granular applicators typically consist of a hopper, a metering system, drop tubes, and a diffuser. The metering system can work one of two ways. In the gravity flow type, the size of an orifice or opening is adjusted, and an agitator ensures smooth delivery. In the positive displacement type, the metering unit delivers a fixed volume of material for every revolution it makes. The drive mechanism is often connected to a ground wheel so material is delivered whenever the wheel turns and the orifice or gate is open. Some units are driven by PTO drives or small electric motors rather than ground drives. Positive displacement systems are generally more accurate.

The metering device must function properly. Clean it regularly to remove caked material or other obstructions. Check the condition of components and replace them if they appear worn. Badly worn components may result in large application errors. Check the tubes and diffusers for leaks or blockage. Drop tubes or hoses should allow the material to fall freely without collecting in the tube. Keep the tubes as nearly vertical as possible.

Broadcast Spreaders

Broadcast spreaders are widely used to apply fertilizer, lime, or amendments on lawns, gardens, or fields. These machines may be small handheld or cart-mounted units for home or garden use, or they may be three-point hitch, trailer-mounted, or truck-mounted units for field use. Spreaders for home or garden use can be simple drop spreaders with a series of holes along the underside of the hopper to meter and spread the material, or they may be spinner spreaders, which use a single spinner to spread the product across the swath. Larger field spreaders can be single spinner, twin spinner, or air boom designs.

A large spinner spreader typically consists of a hopper, a drag chain or belt, a discharge gate, a chute, and one or two spinners. Some smaller units do not use the drag chain but rely on gravity flow through an orifice and an agitator to achieve the desired discharge rate. Larger broadcast spreaders can have a drag chain or belt driven by a ground wheel or by PTO.

Spinner spreaders should produce a pattern that is heavy in the center and tapers to the edges. Desirable patterns for a spinner spreader are the triangle, oval, and flat top patterns shown in Figure 2-1. Proper spacing of the swaths in the field is critical to apply product correctly. Swath spacing should be the width across the pattern where each side delivers 50 percent of the rate (Figure 2-1). If the swath spacing is too wide, some areas will not receive enough product between the passes of the spreader. If the swath spacing it too close, some areas will receive too much product. Be sure to check the spread pattern and maintain proper swath spacing in the field.

Air boom spreaders use a high volume air stream to suspend the product particles and convey them through tubes to diffusers spaced along the boom. The product is metered into an air chamber where the air stream catches the material and divides it into the tubes running to the diffusers. The product is uniformly distributed along the width of the boom with a very slight taper on the outside edges. As with the spinner spreader, proper swath spacing is critical. Because the air boom pattern has little taper, precise spacing must be maintained.

Smooth delivery of material is important. Check the discharge mechanism for blockage or wear. Check the drive mechanism to make sure it is functioning properly. Slipping wheels, worn belts, and worn chains can seriously affect performance and should be repaired. Check the spinners for holes in the bottom or in the vanes. Check for caked material on the vanes as well. Pay close attention to the speed of the spinner; excessively high or low speeds can cause improper application patterns. On air boom spreaders, be sure to check the air chamber and tubes for blockages and leaks. Refer to your operator's manual for correct settings and adjustments on all machines.

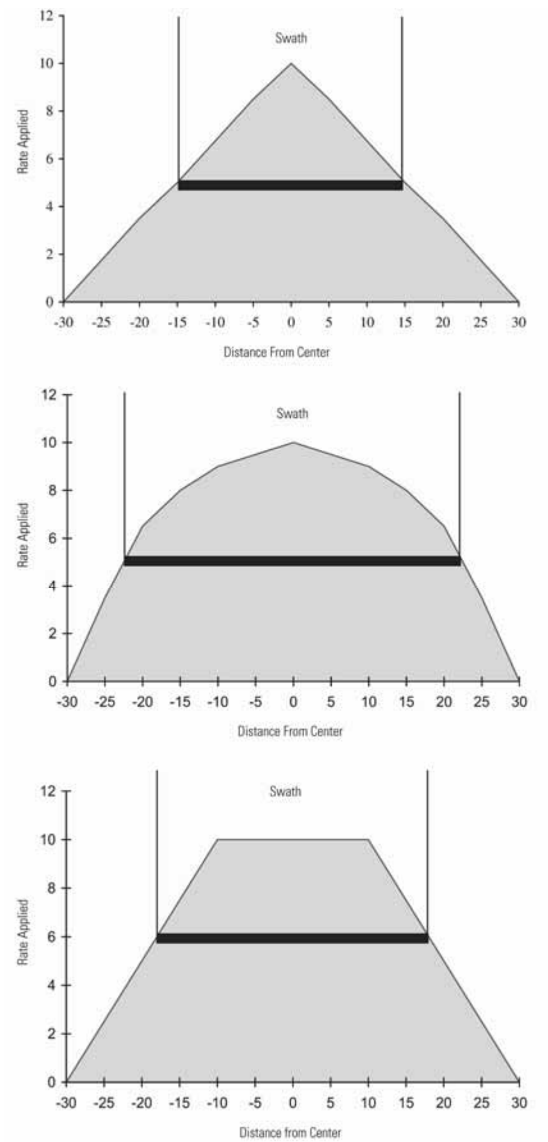

Figure 2-1. Desirable patterns for broadcast spinner spreader are the triangle, oval, and flat top, as shown above.

Sprayers

Most field sprayers in use today are hydraulic; the spray pressure is built up by the action of the pump on the spray mixture. The sprayers range from low- to high-pressure and may be mounted, pull-type, or self-propelled models. There are also electrostatic and air-directed sprayers. Sprayer designs also include boom and boomless units to match a wide range of applications.

The basic components are the tank, pump, agitator, hoses, valves and fittings, and nozzles. Some modern units also incorporate electronic control systems to enhance accuracy and performance. When purchasing a new sprayer or when replacing components, choose carefully to ensure quality.

Two types of sprayer designs are currently available: tank mix and injection. The tank mix design consists of a large tank in which water and chemicals are mixed. Tank mix sprayers are less expensive and easy to operate. Injection sprayers have a large tank that contains only water. A second tank holds the chemical. While more costly to purchase, injection sprayers have the advantage of reduced risk since you never mix more than needed. The tank is never contaminated with chemicals, so cleanup is simpler. Electronic controls are used to measure the flow of water and inject the proper quantity of chemical into the water stream before it is delivered to the nozzles. This design reduces contamination potential and eliminates the need for tank agitation.

Tanks are usually made of stainless steel, aluminum, fiberglass, or plastic and should include a large splash-proof filler. They should be resistant to rust and all chemicals placed in them. Check with your chemical supplier regarding compatibility.

A suction line connection and a drain should be connected at the bottom of the tank. Bottom suction makes the pump self-priming. When possible, use only one tank for the sprayer; multiple tanks are more difficult to agitate properly. The injection sprayer can use multiple tanks without problem since agitation is not required.

Pumps are available in brass, aluminum, cast iron, and corrosion-resistant alloys (Table 2-1). Select a pump material that will not be corroded by the chemical you are using. The pump seal material (for example, leather or neoprene) should be compatible with the chemical.

Pump capacity is measured in gallons per minute (GPM) or gallons per hour (GPH). Select a pump with a capacity at least 50 percent larger than the sum of the nozzle outputs and the agitator. Oversizing the pump compensates for wear and keeps the system running longer. Pumps are usually attached directly to the tractor PTO. They should be allowed to "float" as they rotate. Secure the pump with a length of chain, leaving some slack rather than bolting the pump down rigidly. Hydraulically driven pumps can be mounted on the sprayer frame. Characteristics of various types are listed in Table 2-1.

Jet agitators or mechanical agitators are usually used in sprayer tanks. Place jet agitators in the bottom of the tank and connect to the high-pressure side of the control valve. This arrangement allows full flow to the agitator as well as full pressure control for the nozzles. Check with your sprayer supplier for proper size of agitator nozzles and flow rates. The return line from the pressure regulator is not adequate for agitation.

Every field sprayer should have a sprayer control unit. The control can be manual or electronic. The control should allow the operator to select the section of the boom or nozzles to use and regulate pressure. The control should also have a high accuracy pressure gauge. Measuring and controlling pressure accurately is essential for most sprayer designs. Never shortchange the quality of the pressure gauge.

Electronic control units for sprayers can enhance performance by improving application accuracy. These controls may include pressure sensors, flow rate sensors, or a combination of the two. These controls rely on solenoid or ball valves to control flow to the system and a throttling valve to regulate system pressure. These valves must be checked periodically to ensure proper performance. Some units also include ground speed sensors. By measuring ground speed, the sprayer can compensate for changes in speed and maintain better accuracy.

Electronic or automatic controls can improve accuracy and performance of a sprayer, however, they are ***no substitute for proper calibration.***

Hoses should be oil resistant and durable. They should have a test pressure twice the operating pressure. Suction hoses should be strong enough to prevent collapsing. The hoses should be large enough for proper flow while keeping pressure loss to a minimum (Table 2-2). If a hose is too small, the pressure at the nozzles will be much less than that measured at the control valve, causing under-application. Suction hoses should be at least as large as the pump's intake port.

TABLE 2-1. PUMP TYPES AND CHARACTERISTICS

Pump Type	Available Construction Material	Typical Maximum Pressure (PSI)	Capacity (GPM)	Effect of Abrasives	Repairable
Gear	Bronze	80	3 to 7	Severe	No
Roller[1] (4 to 8)	Cast iron, Ni-resist, or bronze (nylon, Teflon, polypropylene, or rubber rollers)	75 to 150	6 to 68	Moderate	Yes
Centrifugal	Cast iron	50	40[2]	Moderate	Yes
Diaphragm	Cast iron or aluminum	75 to 850	5 to 62	Practically none	Yes
Piston	Cast iron	400 to 600	6 to 24	Moderately little	Yes

[1] Roller pumps are available with rubber rollers in lieu of nylon rollers. The rubber rollers have the longest life when used with abrasive materials, but the maximum pressure is limited to 75 psi. Pumps equipped with rubber rollers cost more.

[2] Capacity for a typical 1.25-in. suction size centrifugal pump. Flow is much greater than at low pressures.

Sprayers should have a suction strainer to protect the pump. Surface area for a suction strainer should be 2 square inches per GPM. Mesh size is determined by the type of chemical used. Use strainers to protect valves and nozzles.

Strainers used on the pressure side should have an area of at least 1 square inch per GPM.

TABLE 2-2. NORMAL PERMISSIBLE HOSE FLOW RATES

Maximum Flow, GPM	2	4	8	12	20	40
Hose Size (in.)	0.375	0.5	0.625	0.75	1	1.25

Nozzles are perhaps the most important part of the sprayer. Unfortunately, no one nozzle can cover every type of application. Nozzles vary according to capacity (GPM or GPH), spray pattern angle, and shape of spray pattern (Table 2-3). Nozzles are usually equipped with strainers to protect them from abrasive particles. Even with protection, nozzles will wear. Check nozzles regularly and replace them if wear is observed.

Electrostatic sprayers offer better plant coverage and more efficient use of chemicals. Electrostatic sprayers use a high-voltage electrical charge to create an electrostatic field between the plant and the spray droplet. The plant and the spray droplet have opposite charges causing them to attract each other. The droplets cling to any exposed plant surface, top or bottom. More uniform coverage and potential for reduced spray volume make electrostatic spraying a cost-effective method of chemical application.

Air-directed sprayers fall into three groups: air boomless, air boom, and air nozzle. Air boomless sprayer have been widely used for years in vineyards and orchards. A nozzle or nozzle cluster sprays into the discharge of a high-volume fan. The airflow spreads the droplets onto the crop. Air boom sprayers are similar to conventional hydraulic sprayers. In addition to the sprayer boom and nozzles, an air tube is added with air ports or nozzles over the sprayer nozzles. The air blast from the air tube blows the spray down into the crop canopy, improving penetration and reducing drift. Air nozzles fall into two categories: pressure and induction. Air pressure nozzles use compressed air to atomize liquid and create the spray pattern rather than water pressure. Because droplet size and pattern are controlled by air pressure, there is no need to have different nozzles for each application rate. Air induction nozzles draw air into the spray stream to control drop formation. The drops formed are larger, air-filled drops that are less likely to drift.

Drift control is an important consideration for any type of sprayer. Drift can be caused by wind at or near the ground or by high nozzle pressures. Drift can also be caused by evaporation of the liquid on hot days. Often a combination of the three is present. Drift contaminates other crops or the surrounding woods and streams. Electrostatic, air boom, and air nozzle sprayers all have drift-reducing potential. Conventional sprayers can also take advantage of drift reducing technology by incorporating spray shields or drift-reducing nozzles.

Backpack Sprayers

Backpack sprayers consist of a tank, a pump, and a spray wand with one or more nozzles. Some sprayers have a pressure-regulating valve or a pressure gauge to help the user maintain desired pressure. Small size, portability, and ease of use make the backpack sprayer a valuable tool for many users. Backpack sprayers are best suited for small acreage, spot spraying, hard-to-reach areas, and other areas where a larger sprayer is impractical.

Most backpack sprayers use hand pumps; however, some units have a small battery or engine-powered pumping system. Regardless, consistent and uniform pressure control is essential to ensure proper application.

Hand-operated sprayers should have a comfortably located, reversible handle (to allow for left- or right-hand use). The shoulder straps should distribute the load evenly across the shoulders. Consider a hip belt to help carry the weight of the larger units. The wand should be comfortable and allow for easy use of the trigger. The sprayer should also have removable screens to protect the pump and nozzles. These should be cleaned regularly. Finally, the sprayer should have a stable base to hold it upright for filling and mixing.

A portable containment and mixing system for backpack sprayers has been developed for use in pickup trucks and utility vehicles. This system secures the backpack to prevent tipping over and provides a means to shake the unit for mixing. Further, hand pumps and meters are provided to allow accurate mixing of doses for the sprayer.

TABLE 2-3. NOZZLE TYPES AND MATERIALS

Nozzle Type	Nozzle Description	Nozzle Material	Material Description
Flat fan	Typically used for broadcast applications.	Brass	Most common material used, relatively inexpensive. High wear rate with abrasive materials.
Even	Typically used for band applications. Pattern is uniform across width. Do not overlap.	Aluminum	Resistant to corrosives. High wear rate with abrasives.
Whirlchamber	Wide-angle hollow cone used in place of flat fan. Minimum clogging and low drift.	Monel	Same as aluminum.
Flooding	Wide spray patterns used for herbicides and fertilizers. Overlapping usually required.	Plastic	Low cost, corrosion resistant, used for nonabrasive materials.
Boomless	Wide swath of 30 ft or more. May be single or cluster nozzles. Coverage not as uniform as boom nozzles and more affected by wind.	Nylon	Noncorrosive, low wear rate with abrasives. May swell when exposed to some chemicals.
Hollow cone	Very uniform distribution and better coverage of crop foliage.	Stainless steel	Noncorrosive but relatively expensive. Low wear rate with abrasives.
Solid cone	Concentrates spray material on plants.	Ceramic	Suitable for use with abrasives at high pressures. Long life.
Off-center	Flat or cone pattern, used on end of boom to increase width of swath.		
Double-outlet	Wider pattern angle and width.		

Wick Applicators

A convenient method to apply contact herbicides is the wick applicator. In this design, a wick (rope, sponge, etc.) is soaked with a solution. Herbicide is applied to the plant target by brushing against the plant. The application rate is controlled by adjusting the chemical solution, the rate it is soaked by the wick, or the speed of travel over the target. Ropes are commonly used as wicks, which explains the name “rope wick applicator.” Wick applicators offer the ability to apply chemical only to a selected target, e.g. weeds and grasses taller than the crop. Reduced chemical usage compared to broadcast spraying is possible.

GPS and Variable Rate Technology

Improved accuracy, site-specific application rates, and higher profitability are among the advantages offered by GPS systems and variable rate applicators. GPS stands for “Global Positioning System.” GPS is a system of navigational satellites established by the military and made available for private use. GPS signals alone are not accurate enough to guide or control field equipment. Differential correction signals (DGPS) must be used to achieve the necessary accuracy. Depending on your location, you may wish to subscribe to a commercial signal service or use one of the free correction signals, such as the Coast Guard Beacon or Wide Area Augmentation System (WAAS). Some systems offer accuracy to within a few inches.

To use the system, a machine such as a tractor, spreader truck, sprayer, or aircraft is equipped with a DGPS receiver. The operator uses the receiver and a computer to guide the equipment across the field. The ability to establish and maintain uniformly spaced swaths is an advantage with GPS guidance systems. Once the swaths are established, a light bar or screen display is used to help the equipment operator stay on course. With the ability to determine position in a field accurately, the grower can take advantage of variable rate control systems and soil, weed, or yield maps prepared for the field. Information from these maps is used to determine the proper amount of material—fertilizer, lime, or pesticides—to apply to each area within the field. Therefore, only the areas that need or will benefit from higher application rates receive those rates, while other areas receive more moderate rates.

Control systems can be selected to manage a single product or multiple products. A single product (also called single channel) controller can be used for granular applicators, broadcast spreaders, or sprayers. Single channel controls for sprayers are used on tank mix sprayer systems. Multiple channel controllers can also be used on broadcast spreaders and sprayers. On broadcast spreaders, multiple channel controllers are used to control rates on multiple hopper spreaders to blend products on the go in the field as called for by prescription maps or commands from the spreader operator. On sprayers, multiple channel controls can be used to inject pesticides into a constant stream of water before the spray is applied through the nozzles. This allows variable rates of pesticides to be applied as indicted on prescription maps for operator commands. Another advantage of the computerized variable rate controls systems is the ability to record a map of the product as it is applied to the field. Application record maps can be valuable assets in a complete management plan.

Cleaning Equipment

Dusters, sprayers, granular applicators, and broadcast spreaders should be cleaned after use. Some chemicals are corrosive and may damage the components if left in the equipment. Other materials may contaminate the next application if allowed to remain.

Rinsate in sprays can often be applied over the crop if it has been diluted properly. Check with your chemical supplier or Extension Center for suggestions. Most sprayers can be equipped with an in-field rinse system for approximately a few hundred dollars. The system consists of a rinse tank, control valves, and hoses to connect it to the sprayer circuit. A rinse nozzle must be installed inside the tank.

Wash the equipment on an approved wash pad or site. Protect components from rust and corrosion after washing with a light oil or other suitable material.

Calibrating Chemical Application Equipment

Purpose

To determine if the proper amount of chemical is being applied, the operator must measure the output of the application equipment. This technique is known as *calibration*.

Calibration not only ensures accuracy, a critical factor with regard to many chemicals, but it can also save time and money and benefit the environment.

Getting Started

Careful and accurate control of ground speed is important for any type of chemical application procedure. From large self-propelled sprayers and spreaders to small walk-behind or backpack units, precise ground speed is a key for success. Ground speed can be determined by one of two methods. The first method requires a test course and stopwatch. For this procedure, measure a suitable test course in the field and record the time it takes to cover the course with the equipment. The course should be between 100 and 300 feet long. Drive or walk the course at least twice, once in each direction, and average the times for greater accuracy. Calculate the speed with Equation 1 or refer to Table 2-6.

Equation 1. Ground Speed (MPH) = $\frac{Distance \ x \ 60}{Seconds \ x \ 88}$

The second method is to use a true ground speed indicator such as a tractor-mounted radar or similar system. Do not rely on transmission speed charts and engine tachometers. They are not accurate enough for calibration.

Calibrating a Sprayer

Preparing to Calibrate

For calibration to be successful, several items need to be taken care of before going to the field. Calibration will not be worthwhile if the equipment is not properly prepared. Whenever possible, calibration should be performed using water only. If you must calibrate using spray mixture, do so on a site listed on the chemical label and with wind speeds less than 5 MPH. Follow the steps outlined below to prepare spraying equipment for calibration.

1. Inspect the sprayer. Be sure all components are in good working order and undamaged. On backpack sprayers, pay particular attention to the pump, control wand, strainers, and hoses. On boom sprayers, pay attention to the pump, control valves, strainers, and hoses. On airblast sprayers, be sure to inspect the fan and air tubes or deflectors as well. Be sure there are no obstructions or leaks in the sprayer.
2. Check the label of the product or products to be applied and record the following:
   - *Application Rate*, Gallons per Acre (GPA)
   - *Nozzle Type*, droplet size and shape of pattern
   - *Nozzle Pressure,* Pounds per Square Inch (PSI)
   - *Type of Application*, broadcast, band, or directed
3. Next, determine some information about the sprayer and how it is to be operated. This includes:
   - *Type of Sprayer:* backpack, boom, or airblast. The type of sprayer may suggest the type of calibration procedure to use.
   - *Nozzle Spacing (inches):* For broadcast applications, nozzle spacing is the distance between nozzles.
   - *Nozzle Spray Width (inches):* For broadcast applications, nozzle spray width is the same as nozzle spacing—the distance between nozzles. For band applications, use the width of the sprayed band if the treated area in the band is specified on the chemical label; use nozzle spacing if the total area is specified. For directed spray applications, use the row spacing divided by the number of nozzles per row. Some directed spray applications use more than one type or size of nozzle per row. In this case, the nozzles on each row are added together and treated as one. Spray width would be the row spacing.
   - In most cases, a backpack sprayer uses a single nozzle. Some sprayers use mini-booms or multiple nozzles. The spray width is the effective width of the area sprayed, being sure to account for overlap. If you are using a sweeping motion from side to side, be sure to use the full width sprayed as you walk forward. If you are spraying on foliage in a row, use the row spacing. Dyes are available to blend with the spray to show what has been covered.
   - *Spray Swath (feet):* The width covered by all the nozzles on the boom of a sprayer. For airblast or other boomless sprayers, it is the effective width covered in one pass through the field.
   - *Ground Speed, miles per hour (MPH).* When using a backpack sprayer, walk a comfortable pace that is easy to maintain. Slow walking speeds will take longer to complete the task, while high speeds may be tiresome. Choose a safe, comfortable speed that will enable you to finish the job in a timely manner. On tractor-mounted sprayers, select a ground speed appropriate for the crop and type of sprayer used. Slow speeds will take longer to complete the task, while high speeds may be difficult to control and unsafe. Choose a safe, controllable speed that will enable you to finish the job in a timely manner. Ground speed can be determined from Equation 1 or Table 2-6.
4. The *discharge rate, gallons per minute (GPM),* required for the nozzles must be calculated in order to choose the right nozzle size. Discharge rate depends on the application rate; ground speed; and nozzle spacing, spray width, or spray swath.

For applications using nozzle spacing or nozzle spray width (inches), use Equation 2 or Table 3-9:

Equation 2. Discharge Rate =

$$\frac{Application\ Rate\ x\ Ground\ Speed\ x\ Nozzle\ Spray\ Width}{5{,}940}$$

For applications using the spray swath (feet):

Equation 3. Discharge Rate =

$$\frac{Application\ Rate\ x\ Ground\ Speed\ x\ Spray\ Swath}{495}$$

5. Choose an appropriate nozzle or nozzles from the manufacturer's charts and install on the sprayer. Check each nozzle to be sure it is clean and that the proper strainer is installed with it.
6. Fill the tank half full of water and adjust the nozzle pressure to the recommended setting. Measure the discharge rate for the nozzle. This can be done by using a flow meter or by using a collection cup and stopwatch. The flow meter should read in gallons per minute (GPM). If you are using the collection cup and stopwatch method, the following equation is helpful to convert ounces collected and collection time, in seconds, into gallons per minute.

Equation 4. Discharge Rate =

$$\frac{Ounces\ Collected\ x\ 60}{Collection\ Time\ x\ 128}$$

7. Whenever possible, calibrate with water instead of spray solution. Do not calibrate with spray solution unless required by the chemical label. Follow all recommendations on the label. If the spray solution has a density different than water, the rate can be corrected using the procedure shown in Calibration Variables.
8. On boom sprayers or sprayers with multiple nozzles, average the discharge rates of all the nozzles on the sprayer. Reject any nozzle that has a bad pattern or that has a discharge rate 10 percent more or less than the overall average. Install a new nozzle to replace the rejected one and measure its output. Calculate a new average and recheck the nozzles compared to the new average. Again, reject any nozzle that is 10 percent more or less than the average or has a bad pattern. When finished, select a nozzle that is closest to the average to use later as your "quick check" nozzle.
9. On backpack sprayers or sprayers with a single nozzle, compare the discharge rate of the nozzle on the sprayer to the manufacturer's tables for that nozzle size. Reject any nozzle that has a bad pattern or that has a discharge rate 10 percent more or less than the advertised rate. Install a new nozzle to replace the rejected one and measure its output.

Once the sprayer has been properly prepared for calibration, select a calibration method. When calibrating a sprayer, changes are often necessary to achieve the application rates needed. The sprayer operator needs to understand the changes that can be made to the adjust rate and the limits of each adjustment. The adjustments and the recommended approach are:

- *Pressure:* if the error in application rate is less than 10 percent, adjust the pressure.
- *Ground speed:* if the error is greater than 10 percent but less than 25 percent, change the ground speed of the sprayer.
- *Nozzle size:* if the error is greater than 25 percent, change nozzle size.

The goal is to have application rate errors less than 5 percent.

Calibration Methods

There are four methods commonly used to calibrate a sprayer:

- basic
- nozzle
- 128th acre
- area

The basic, nozzle, and 128th acre methods are time-based methods that require using a stopwatch or watch with a second hand to ensure accuracy. The area method is based on spraying a test course measured in the field. Each method offers certain advantages. Some are easier to use with certain types of sprayers. For example, the basic and area methods can be used with any type of sprayer. The 128th acre and nozzle methods work well for boom and backpack sprayers. Choose a method you are comfortable with and use it whenever calibration is needed.

Basic Method

1. Accurate ground speed is very important to good calibration with the basic method. For tractor-mounted sprayers, set the tractor for the desired ground speed and run the course at least twice. For backpack sprayers, walk the course and measure the time required. Walk across the course at least twice. Average the times required for the course distance and determine ground speed from Equation 1 or Table 2-6.
2. Calculate the application rate based on the average discharge rate measured for the nozzles, the ground speed over the test course, and the nozzle spacing, nozzle spray width, or spray swath on the sprayer.

   When using nozzle spacing or nozzle spray width measured in inches, use the following equation:

Equation 5. Application Rate =

$$\frac{5{,}940\ x\ Discharge\ Rate}{Ground\ Speed\ x\ Nozzle\ Spray\ Width}$$

For spray swath applications measured in feet:

Equation 6. Application Rate =

$$\frac{495\ x\ Discharge\ Rate}{Ground\ Speed\ x\ Spray\ Swath}$$

3. Compare the application rate calculated to the rate required. If the rates are not the same, choose the appropriate adjustment and reset the sprayer.
4. Recheck the system if necessary. Once you have the accuracy you want, calibration is complete.

Nozzle Method

1. Accurate ground speed is very important to good calibration with the nozzle method. For tractor-mounted sprayers, set the tractor for the desired ground speed and run the course at least twice. For backpack sprayers, walk the course and measure the time required. Walk across the course at least twice. Average the times required for the course distance and determine ground speed from Equation 1 or Table 2-6.
2. Calculate the nozzle discharge rate based on the application rate required, the ground speed over the test course, and the nozzle spacing, spray width, or spray swath of the sprayer. For nozzle spacing or spray width

measured in inches use the following table (or refer to Table 2-9):

Equation 7. Discharge Rate =

$$\frac{Application\ Rate\ x\ Speed\ x\ Spray\ Width}{5{,}940}$$

For spray swath measured in feet:

Equation 8. Discharge Rate =

$$\frac{Application\ Rate\ x\ Speed\ x\ Spray\ Width}{495}$$

Set the sprayer and determine the average nozzle rate.

3. Compare the rate calculated to the average rate from the nozzles. If the two don't match, choose the appropriate adjustment and reset the system.
4. Recheck the system if necessary. Once you have the accuracy you want, calibration is complete.

128th Acre Method

1. The distance for one nozzle to cover 128th of an acre must be calculated. The nozzle spacing or spray width in inches is used to determine the spray distance. Spray distance is measured in feet. On backpack sprayers, be sure to measure the full width sprayed as you walk forward. Use Equation 9 or Table 2-14.

Equation 9. Spray Distance =

$$\frac{4{,}084}{Spray\ Width}$$

2. Measure the spray distance on a test course in the field. Check the ground speed as you travel across the course. Be sure to maintain an accurate and consistent speed. Travel the course at least twice and average the time to cover the course.
3. For backpack sprayers, collect the output from the nozzle for the time measured in step 2. For tractor-mounted sprayers, park the sprayer, select the nozzle closest to the average, and collect the output for the time determined in step 4. Ounces collected will equal application rate in GPA.
4. Compare the application rate measured for the nozzle to the rate determined in step 3. If the rates are not the same, choose the appropriate adjustment and reset the system.
5. Recheck the system if necessary. Once you have the accuracy you want, calibration is complete.

Area Method

1. Determine the distance that can be sprayed by one tank using the full spray swath measured in feet.

Equation 10. Tank Spray Distance (ft) =

$$\frac{Tank\ Volume\ (gal) x\ 43{,}560}{Application\ Rate\ (GPA) x\ Swath\ (ft)}$$

2. Lay out a test course that is at least 10 percent of the tank spray distance from Step 1. Fill the sprayer tank with water only, mark the level in the tank, set the sprayer as recommended, and spray the water out on the course. Be sure to maintain an accurate and consistent speed.
3. After spraying the test course, carefully measure the volume of water required to refill the tank to the original level. Calculate the application rate as shown:

Equation 11. Application Rate (GPA) =

$$\frac{Volume\ Sprayed\ (gal) x\ 43{,}560}{Test\ Course\ Distance\ (ft) x\ Swath\ (ft)}$$

4. Compare the application rate measured to the rate required. If the rates are not the same, choose the appropriate adjustment method and reset the sprayer.
5. Recheck the system. Once you have the accuracy you want, calibration is complete.

Calibrating a Granular Applicator

Preparing to Calibrate

Granular application calibration is usually done with the chemical to be applied. It is difficult to find a blank material that matches the granular product. Extra care should be taken in handling this product. Minimize worker exposure and take precautions against spills during calibration.

To prepare for calibration, follow these steps:

1. Before calibrating, carefully inspect the equipment to ensure that all components are in proper working order. Check the hopper, the metering rotor, the orifice, and the drop tubes. Be sure there are no leaks or obstructions.
2. Determine the type of application required for the product:
   - Broadcast: treats the entire area (includes band applications based on broadcast rates).
   - Band: treats only the area under the band.
   - Row: treats along the length of the row.
3. Determine the application rate needed:
   - Broadcast: pounds per acre.
   - Band: pounds per acre of treated band width.
   - Row: pounds per acre or pounds per 1,000 feet of row length.
4. What type of drive system does the applicator use:
   - Independent: uses PTO, hydraulic, or electric motor drive.
   - Ground Drive: uses ground driven wheel.
4. Regardless of how the application rate is expressed or type of application, calibration is easier if the rate is expressed in terms of pounds per foot of row length. Use one of the following steps to determine the correct row rate in pounds per foot.

For broadcast and row applications (Application Rate = lb/ac):

Equation 12. Row Rate, lb/ft =

$$\frac{Application\ Rate\ x\ Row\ Width\ (ft)}{43{,}560}$$

For banded applications (Application Rate = lb/ac of Band Width):

Equation 13. Row Rate, lb/ft =

$$\frac{Application\ Rate\ x\ Band\ Width\ (ft)}{43{,}560}$$

For directed (row) applications (Application Rate = lb per 1,000 ft):

Equation 14. Row Rate, lb/ft =

$$\frac{Application\ Rate}{1{,}000}$$

6. Choose a calibration distance to work with and measure a test course of this distance in the field you will be working

in. Choose an area that is representative of field conditions. The calibration distance should be at least 50 feet but not more than 500 feet. Longer distances are generally more accurate.

7. Calculate the weight of material that should be collected for the calibration distance chosen.

Equation 15. Weight Collected =

$$Row\ Rate\ x\ Calibration\ Distance$$

8. Select a ground speed appropriate for the crop and type of equipment used. Slow speeds take longer to finish the task, while high speeds may be inefficient and unsafe. Consult your equipment manual for a recommended speed. Even ground-driven application equipment can be sensitive to changes in speed. Maintaining an accurate and consistent speed is very important. Choose a safe, controllable speed that will enable you to complete the job in a timely and efficient manner.
9. Set your equipment according to recommendations from the equipment or chemical manufacturer. Most equipment manufacturers and chemical manufacturers provide rate charts to determine the correct orifice setting or rotor speed for each applicator. Fill the hopper at least half full to represent average capacity for calibration.
10. Attach a suitable collection container to each outlet on the applicator. You should be able to collect all material discharged from the applicator. Locate a scale capable of weighing the samples collected in calibration. Some samples may be very small, so a low-capacity scale may be needed. An accurate scale is very important.

Calibration Methods

Two methods for calibrating granular applicators are commonly used. The first is the distance method. This method is preferred by many operators because it applies to any type of granular machine and is easy to perform. The second method is the time method. This method is similar to sprayer calibration and can be used for applicators driven by PTO, hydraulic, or electric motors.

Distance Method

1. On the test course selected in the field, collect the output from the applicator in a container as you travel the course and weigh the material collected. Record the time required to travel the course also. Run the course twice, once in each direction, and average the results for both weight and time.
2. Determine the weight of the product that should be collected for the calibration distance.

Equation 16. Weight Collected (lb) =

$$Row\ Rate\ (lb/ft)\ x\ Calibration\ Distance\ (ft)$$

Time Method

1. On the test course selected in the field, record the time required to travel the course. Run the course twice, once in each direction, and average the results. Accurate ground speed is very important to good calibration with the time method.
2. With the equipment parked, set the orifice control as recommended and run the applicator for the time measured to run the calibration distance. Collect and weigh the output of the applicator for this time measurement.
3. Determine the weight of the product that should be collected for the calibration distance.

Equation 17. Weight Collected (lb) =

$$Row\ Rate\ (lb/ft)\ x\ Calibration\ Distance\ (ft)$$

4. Compare the weight of the product actually collected during the time it took to cover the calibration distance to the weight expected for the calibration distance. If the rates differ by more than 10 percent, adjust the orifice, rotor speed, or ground speed and repeat. Bear in mind, speed adjustments are not effective for ground-driven equipment.
5. Repeat the procedure until the error is less than 10 percent.

Calibrating a Broadcast Spreader

1. Carefully inspect all machine components. Repair or replace any elements that are not in good working order.
2. Determine the type of drive system that is being used: ground drive or independent PTO. This may help determine the method of calibration.
3. Determine the application rate and the bulk density of the product to be applied.
4. Determine the spreader pattern and swath of the spreader. Check the pattern to ensure uniformity. To check the pattern, place collection pans across the path of the spreader. For drop spreaders, be sure to place a pan under each outlet. For centrifugal and pendulum spreaders, space the pans uniformly with one in the center and an equal number on each side. The pattern should be the same on each side of the center and should taper smoothly as you go to the outer edge. The swath would be set as the width from side to side where a pan holds 50 percent of the maximum amount collected in the center pan.
5. Fill the hopper half full to simulate average conditions.
6. Set the ground speed of the spreader.
7. Set the spreader according to the manufacturer's recommendations and begin calibration.

Calibration Methods

There are two common methods used to calibrate broadcast spreaders. The first method is the discharge method. To use this procedure, collect and measure the total discharge from the spreader as it runs across a test course. The second method, the pan method, is used on centrifugal and pendulum spreaders. The pattern test pans used to determine pattern shape and swath are used to determine the application rate.

Discharge Method

1. Determine the test distance to use. Longer distances may give better accuracy but may be difficult to manage. A distance of 300 to 400 feet is usually adequate. Use shorter distances if necessary to avoid collecting more material than you can reasonably handle or weigh.
2. Set the ground speed. Be sure to maintain a constant ground speed at all times.
3. If using a ground drive spreader, attach a collection bin to the discharge chute or under the outlets and collect all the material discharged from the spreader as it runs across the test distance. If using an independent drive spreader, record the time required to run the test course. Park the spreader at a convenient location and measure the discharge from the spreader for the time measured on the test distance. The course should be run twice and the times averaged for better accuracy.

4. Calculate the application rate (pounds per acre):

Equation 18. Application Rate, lb/ac =

$$\frac{Weight\ Collected\ (lb) x\ 43{,}560}{Distance\ (ft) x\ Swath\ (ft)}$$

5. Compare the application rate measured to the rate required. Adjust and repeat as necessary.

Pan Method

1. Place pans in the field across the swath to be spread. Pans should be uniformly spaced to cover the full swath. One pan should be at the center of the swath with equal numbers of pans on each side. Use enough pans, 11 or more, to get a good measurement.
2. Make three passes with the spreader using the driving pattern to be used in the field. One pass should be directly over the center pan and the other passes at the recommended distance, lane spacing, to the left and right of the center pass.
3. Combine the material collected in the pans and determine the weight or volume collected. Divide by the number of pans used to determine the average weight or volume per pan.
4. Calculate the application rate.

If you are measuring the weight in the pans in grams:

Equation 19. Application Rate, lb/ac =

$$\frac{13{,}829\ x\ Weight\ (grams)}{Pan\ Area\ (square\ inches)}$$

If you are measuring the volume in the pans in cubic centimeters (cc):

Equation 20. Application Rate, lb/ac =

$$\frac{13{,}829\ x\ Bulk\ Density\ (lb\ per\ cubic\ ft) x\ Volume\ (cc)}{Pan\ Area\ (square\ inches) x\ 62.4}$$

5. Compare the rate measured to the rate required.

Calibration Variables

Several factors can affect proper calibration. The ground speed of any type of PTO-powered machine can make a difference. On the other hand, ground-driven machines are usually only slightly affected by changes in ground speed. If using dry or granular material, product density will affect the discharge rate and may change the pattern for broadcast spreaders. For liquids, calibration can be affected by pressure, nozzle size, density and viscosity of the liquid, and application type: band or broadcast. The following adjustments may help in adjusting these variables.

Speed

For PTO-powered equipment or other equipment in which the discharge rate is independent of ground speed, Equation 10 is useful.

Equation 21. New Application Rate =

$$Old\ Application\ Rate\ x\ \frac{Old\ Speed}{New\ Speed}$$

For ground-driven equipment, there should be little or no change in application rate when speed is changed.

Pressure

For liquids in sprayers, the discharge rate changes in proportion to the square root of the ratio of the pressures.

Equation 22. New Discharge Rate =

$$Old\ Discharge\ Rate = \sqrt{\frac{New\ pressure}{Old\ Pressure}}$$

Density

For liquids in sprayers, the discharge rate changes if the specific gravity (S.G.) of the liquid changes. Use water for calibration and adjust as shown below. Calibrate with spray solution only if recommended by the supplier.

Equation 23. Water Discharge Rate =

$$Spray\ Discharge\ Rate\ x\ \sqrt{S}.G.of\ Spray\ Solution$$

Band Application Versus Broadcast Application

Some pesticide application recommendations are based on area of cropland covered. Other recommendations are based on area of land treated in the band covered. Check the label for the product you are using to see how it is listed.

Broadcast application is based on area of cropland covered. Nozzle spacing is the distance between nozzles. Band applications in which the area of covered cropland is used for calibration and those applications in which multiple nozzles per row are used are both treated like broadcast applications. Divide the row spacing by the number of nozzles used per row to get a nozzle spacing for calibration.

For band applications in which area of treated land—not cropland covered—is specified, use the width of the band at the ground as the spacing for calibration.

Determining Upper and Lower Limits

Upper and lower limits provide a range of acceptable error. To set these limits for a given sample size, use the equations below. First, however, you must decide upon the degree of accuracy you wish to achieve. Select a percent error: 2 percent, 5 percent, 10 percent, or any other level of accuracy.

Equation 24. Upper Limit =

$$Target\ Rate\ x\ 1 + \frac{Percent\ Error}{100\%}$$

Equation 24. Lower Limit =

$$Target\ Rate\ x\ 1 + \frac{Percent\ Error}{100\%}$$

Useful Tables and Data

TABLE 2-4. WEIGHTS AND MEASURES

Weights

28.35 grams = 1 ounce
16 ounces = 1 pound = 453.6 grams
1 kilogram = 1,000 grams = 2.205 pounds
1 gallon water = 8.34 pounds = 3.8 kilograms
1 cubic foot water = 62.4 pounds = 28.3 kilograms
1 kilogram water = 33.81 ounces = 2.205 pounds
1 gallon No. 2 fuel oil = 7 pounds
1 gallon kerosene = 6.7 pounds
1 ton = 2,000 pounds = 907 kilograms
1 metric ton = 1,000 kilograms = 2,205 pounds

Length and Land Measure

1 inch = 2.54 centimeters
100 centimeters = 1 meter = 3.281 feet
16.5 feet = 5.5 yards = 1 rod
66 feet = 4 rods = 1 chain
1 mile = 5,280 feet = 1.609 kilometers
272.5 square feet = 30.25 square yards = 1 square rod
4,356 square feet = 16 square rods = 1 square chain
43,560 square feet = 160 square rods = 1 acre
43,560 square feet = 10 square chains = 1 acre
1 acre = 0.4047 hectare = 4,047 square meters
1 hectare = 2.471 acres = 10,000 square meters

Volume and Liquid Measure

3 teaspoons = 1 tablespoon = 14.8 cubic centimeters
2 tablespoons = 1 fluid ounce = 29.6 cubic centimeters
8 fluid ounces = 16 tablespoons = 1 cup = 236.6 cubic centimeters
2 cups = 32 tablespoons = 1 pint = 473.1 cubic centimeters
2 pints = 64 tablespoons = 1 quart = 946.2 cubic centimeters
1 liter = 1,000 cc = 0.2642 gallons = 33.81 ounces
4 quarts = 256 tablespoons = 1 gallon = 3,785 cubic centimeters
1 gallon = 128 fluid ounces = 231 cubic inches = 3,785 cubic centimeters
1 bushel = 1.244 cubic feet = 9.309 liquid gallons = 35.2 liters
1 cubic centimeter = 1 milliter

TABLE 2-5. LENGTH OF ROW REQUIRED FOR 1 ACRE

Row Spacing (inches)	Length or Distance
24	7,260 yards = 21,780 feet
30	5,808 yards = 17,424 feet
36	4,840 yards = 14,520 feet
42	4,149 yards = 12,447 feet
48	3,630 yards = 10,890 feet
54	3,227 yards = 9,860 feet
60	2,904 yards = 8,712 feet

TABLE 2-6. TRAVEL SPEED CHART

Miles per Hour	Time Required to Travel (in seconds)		
	100 ft	200 ft	300 ft
1	68	136	205
2	34	68	102
3	23	45	68
4	17	34	51
5	14	27	41
6	11	23	34
7	10	20	29
8	9	17	26
9	8	15	23
10	7	14	21

TABLE 2-7. DILUTIONS FOR LIQUIDS AND DUSTS

Equivalent Quantities of Liquid Materials When Mixed by Parts

Water	1 to 400	1 to 800	1 to 1,600
100 gal	1 qt	1 pt	1 cup
50 gal	1 pt	1 cup	1/2 cup
5 gal	2 tbsp	5 tsp	2-1/2 tsp
1 gal	2 tsp	1 tsp	1/2 tsp

Example: If a recommendation calls for 1 part of the chemical to 800 parts of water, it would take 5 tsp in 5 gal of water to give 5 gal of a mixture of 1 to 800.

Equivalent Quantities of Dry Materials (Wettable Powders) for Various Quantities of Water

Water	Quantity of Material					
100 gal	1 lb	2 lb	3 lb	6 lb	5 lb	4 lb
50 gal	8 oz	1 lb	1.5 lb	3 lb	2.5 lb	2 lb
5 gal	3 tbsp	1.5 oz	2.5 oz	5 oz	4 oz	3.25 oz
1 gal	2 tsp	1 tbsp	1.5 tbsp	1 oz	5 tsp	2 tbsp

Example: If a recommendation calls for a mixture of 4 lb of a wettable powder to 100 gal of water, it would take 3.25 oz (approximately 6.5 tsp) to 5 gal of water to give 5 gal of the spray mixture of the same strength.

Note: Wettable pesticide materials vary considerably in density. Therefore, the teaspoonful (tsp) and tablespoonful (tbsp) measurements in this table are not exact dosage by weight but are within the bounds of safety and efficiency for mixing small amounts of spray.

Equivalent Quantities of Liquid Materials (Emulsion, Concentrates, etc.) for Various Quantities of Water

Water	Quantity of Material					
Example	0.5 pt	1 pt	2 pt	5 pt	4 pt	3 pt
	4 fl oz	8 fl oz	1 pt	2.5 pt	1 qt	24 fl oz
	1 tbsp	1 fl oz	1.5 fl oz	4 fl oz	3 fl oz	2.5 fl oz
	0.5 tsp	1 tsp	2 tsp	5 tsp	4 tsp	3 tsp

Example: If 4 pt of liquid concentrate are recommended to 100 gal of water, 4 tsp of the chemical to 1 gal of water will give a mixture of the same strength.

TABLE 2-8. CHEMICAL FORMULATIONS

Pounds of Active Ingredients Per Gallon, Pounds Per Pint of Liquid, and the Number of Pints for Various Per Acre Rates

Pounds of Active Ingredients In 1 Gallon of Commercial Products	Pounds of Active Ingredients per Pint	Pints of Commercial Product Needed for Each Acre to Give the Following Pounds of Active Ingredient per Acre					
		0.25	**0.50**	**0.75**	**1**	**1.5**	**2**
1.00	0.125	2.00	4.00	6.00	8.00	12.0	16.00
2.00	0.250	1.00	2.00	3.00	4.00	6.0	8.00
2.64	0.330	0.75	1.50	2.25	3.00	4.5	6.00
3.00	0.380	0.67	1.33	2.00	2.67	4.0	5.33
3.45	0.420	0.60	1.20	1.08	2.40	3.6	4.80
4.00	0.500	0.50	1.00	1.50	2.00	3.0	4.00
6.00	0.750	0.33	0.67	1.00	1.33	2.0	2.67

Available Commercial Materials in Pounds Active Ingredients Per Gallon Necessary to Make Various Percentage Concentration Solution

Pounds of Active Ingredients In 1 Gallon of Commercial Products	Pounds of Active Ingredients per Pint	Liquid Ounces of Commercial Product per 1 Gallon of Solution to Make:				
		0.5%	**1%**	**2%**	**5%**	**10%**
1.00	0.125	5.34	10.68	21.35	53.38	106.80
2.00	0.250	2.68	5.36	10.72	26.80	53.40
2.64	0.330	2.02	4.05	8.10	20.25	40.44
3.00	0.380	1.78	3.56	7.12	17.80	35.58
3.34	0.420	1.59	3.18	6.36	15.90	31.96
4.00	0.500	1.33	2.67	5.33	13.34	26.69
6.00	0.750	0.89	1.78	3.56	8.90	17.79

(Based on 8.34 lb per gal (weight of water).

TABLE 2-9. REQUIRED NOZZLE DISCHARGE RATES (GALLONS PER MINUTE) FOR VARIOUS APPLICATION RATES, NOZZLE SPACINGS, AND TRAVEL SPEEDS

Travel Speed (MPH)	Nozzle Spacing (inches)	Application Rate (gallons per acre)							
		5	7.5	10	12.5	15	20	25	35
3	6	0.0152	0.0227	0.0303	0.0379	0.0455	0.0606	0.0758	0.106
	8	0.0202	0.0303	0.0404	0.0505	0.0606	0.0808	0.101	0.141
	10	0.0253	0.0379	0.0505	0.0631	0.0758	0.101	0.126	0.177
	12	0.0303	0.0455	0.0606	0.0758	0.0909	0.121	0.152	0.212
	14	0.0354	0.053	0.0707	0.0884	0.106	0.141	0.177	0.247
	16	0.0404	0.0606	0.0808	0.101	0.121	0.162	0.202	0.283
	18	0.0455	0.0682	0.0909	0.114	0.136	0.182	0.227	0.318
	20	0.0505	0.0758	0.101	0.126	0.152	0.202	0.253	0.354
	21	0.053	0.0795	0.106	0.133	0.159	0.212	0.265	0.371
	22	0.0556	0.0833	0.111	0.139	0.167	0.222	0.278	0.389
	24	0.0606	0.0909	0.121	0.152	0.182	0.242	0.303	0.424
	30	0.0758	0.114	0.152	0.189	0.227	0.303	0.379	0.53
	36	0.0909	0.136	0.182	0.227	0.273	0.364	0.455	0.636
	42	0.106	0.159	0.212	0.265	0.318	0.424	0.53	0.742
	48	0.121	0.182	0.242	0.303	0.364	0.485	0.606	0.848
	60	0.152	0.227	0.303	0.379	0.455	0.606	0.758	1.06
4	6	0.0202	0.0303	0.0404	0.0505	0.0606	0.0808	0.101	0.141
	8	0.0269	0.0404	0.0539	0.0673	0.0808	0.108	0.135	0.189
	10	0.0337	0.0505	0.0673	0.0842	0.101	0.135	0.168	0.236
	12	0.0404	0.0606	0.0808	0.101	0.121	0.162	0.202	0.283
	14	0.0471	0.0707	0.0943	0.118	0.141	0.189	0.236	0.330
	16	0.0539	0.0808	0.108	0.135	0.162	0.215	0.269	0.377
	18	0.0606	0.0909	0.121	0.152	0.182	0.242	0.303	0.424
	20	0.0673	0.101	0.135	0.168	0.202	0.269	0.337	0.471
	21	0.0707	0.106	0.141	0.177	0.212	0.283	0.354	0.495
	22	0.0741	0.111	0.148	0.185	0.222	0.296	0.370	0.519
	24	0.0808	0.121	0.162	0.202	0.242	0.323	0.404	0.566
	30	0.101	0.152	0.202	0.253	0.303	0.404	0.505	0.707
	36	0.121	0.182	0.242	0.303	0.364	0.485	0.606	0.848
	42	0.141	0.212	0.283	0.354	0.424	0.566	0.707	0.990
	48	0.162	0.242	0.323	0.404	0.485	0.646	0.808	1.130
	60	0.202	0.303	0.404	0.505	0.606	0.808	1.010	1.410
5	6	0.0253	0.0379	0.0505	0.0631	0.0758	0.101	0.126	0.177
	8	0.0337	0.0505	0.0673	0.0842	0.101	0.135	0.168	0.236
	10	0.0421	0.0631	0.0842	0.105	0.126	0.168	0.210	0.295
	12	0.0505	0.0758	0.101	0.126	0.152	0.202	0.253	0.354
	14	0.0589	0.0884	0.118	0.147	0.177	0.236	0.295	0.412
	16	0.0673	0.101	0.135	0.168	0.202	0.269	0.337	0.471
	18	0.0758	0.114	0.152	0.189	0.227	0.303	0.379	0.530
	20	0.0842	0.126	0.168	0.210	0.253	0.337	0.421	0.589
	21	0.0884	0.133	0.177	0.221	0.265	0.354	0.442	0.619
	22	0.0926	0.139	0.185	0.231	0.278	0.370	0.463	0.648
	24	0.101	0.152	0.202	0.253	0.303	0.404	0.505	0.707
	30	0.126	0.189	0.253	0.316	0.379	0.505	0.631	0.88
	36	0.152	0.227	0.303	0.379	0.455	0.606	0.758	1.060
	42	0.177	0.265	0.354	0.442	0.530	0.707	0.884	1.240
	48	0.202	0.303	0.404	0.505	0.606	0.808	1.010	1.410
	60	0.253	0.379	0.505	0.631	0.758	1.010	1.260	1.770

TABLE 2-10. TIME (IN SECONDS) NEEDED TO COLLECT 1 PINT (0.125 GALLON) OF LIQUID FROM A SINGLE NOZZLE AT VARIOUS APPLICATION RATES, NOZZLE SPACINGS, AND TRAVEL SPEEDS

Travel Speed (MPH)	Nozzle Spacing (inches)	Application Rate (gallons per acre)							
		5	7.5	10	12.5	15	20	25	35
3	6	495	330	247	198	165	124	99	70.7
	8	371	247	186	148	124	92.8	74.3	53
	10	297	198	148	119	99	74.3	59.4	42.4
	12	247	165	124	99	82.5	61.9	49.5	35.4
	14	212	141	106	84.9	70.7	53	42.4	30.3
	16	186	124	92.8	74.3	61.9	46.4	37.1	26.5
	18	165	110	82.5	66	55	41.3	33	23.6
	20	148	99	74.3	59.4	49.5	37.1	29.7	21.2
	21	141	94.3	70.7	56.6	47.1	35.4	28.3	20.2
	22	135	90	67.5	54	45	33.8	27	19.3
	24	124	82.5	61.9	49.5	41.3	30.9	24.8	17.7
	30	99	66	49.5	39.6	33	24.8	19.8	14.1
	36	82.5	55	41.3	33	27.5	20.6	16.5	11.8
	42	70.7	47.1	35.4	28.3	23.6	17.7	14.1	10.1
	48	61.9	41.3	30.9	24.8	20.6	15.5	12.4	8.84
	60	49.5	33	24.8	19.8	16.5	12.4	9.9	7.07
4	6	371	247	186	148	124	92.8	74.3	53
	8	278	186	139	111	92.8	69.6	55.7	39.8
	10	223	148	111	89.1	74.3	55.7	44.5	31.8
	12	186	124	92.8	74.3	61.9	46.4	37.1	26.5
	14	159	106	79.6	63.6	53	39.8	31.8	22.7
	16	139	92.8	69.6	55.7	46.4	34.8	27.8	19.9
	18	124	82.5	61.9	49.5	41.3	30.9	24.8	17.7
	20	111	74.3	55.7	44.5	37.1	27.8	22.3	15.9
	21	106	70.7	53	42.4	35.4	26.5	21.2	15.2
	22	101	67.5	50.6	40.5	33.8	25.3	20.3	14.5
	24	92.8	61.9	46.4	37.1	30.9	23.2	18.6	13.3
	30	74.3	49.5	37.1	29.7	24.8	18.6	14.8	10.6
	36	61.9	41.3	30.9	24.8	20.6	15.5	12.4	8.84
	42	53	35.4	26.5	21.2	17.7	13.3	10.6	7.58
	48	46.4	30.9	23.2	18.6	15.5	11.6	9.28	6.63
	60	37.1	24.8	18.6	14.8	12.4	9.28	7.72	5.3
5	6	297	198	148	119	99	74.3	59.4	42.4
	8	223	148	111	89.1	74.3	55.7	44.5	31.8
	10	178	119	89.1	71.3	59.4	44.5	35.6	25.5
	12	148	99	74.3	59.4	49.5	37.1	29.7	21.2
	14	127	84.9	63.6	50.9	42.4	31.8	25.5	18.2
	16	111	74	55.7	44.5	37.1	27.8	22.3	15.9
	18	99	66	49.5	39.6	33	24.8	19.8	14.1
	20	89.1	59.4	44.5	35.6	29.7	22.3	17.8	12.7
	21	84.9	56.6	42.4	33.9	28.3	21.2	17	12.1
	22	81	54	40.5	32.4	27	20.3	16.2	11.6
	24	74.3	49.5	37.1	29.7	24.8	18.6	14.8	10.6
	30	59.4	39.6	29.7	23.8	19.8	14.8	11.9	8.49
	36	49.5	33	24.8	19.8	16.5	12.4	9.9	7.07
	42	42.4	28.3	21.2	17	14.1	10.6	8.49	6.06
	48	37.1	24.8	18.6	14.8	12.4	9.28	7.42	5.3
	60	29.7	19.8	14.8	11.9	9.9	7.42	5.94	4.24

TABLE 2-11. FUMIGANT APPLICATION RATE TABLE

Application Rate (gal/acre)	Quantity Per 100 Ft at Given Bandwidth													
	8-Inch Width		12-Inch Width		24-Inch Width		30-Inch Width		36-Inch Width		42-Inch Width		48-Inch Width	
	oz	cc	oz	cc	oz	cc	oz	cc	oz	cc	oz	cc	oz	cc
1	0.2	6	0.3	9	0.6	17	0.7	22	0.9	26	1.0	30	1.2	35
3	0.6	17	0.9	26	1.7	52	2.2	65	2.6	78	3.1	91	3.5	104
5	1.0	29	1.5	44	2.9	87	3.7	109	4.4	130	5.1	152	5.9	174
7	1.4	41	2.1	61	4.1	122	5.1	152	6.2	183	7.2	213	8.2	243
9	1.8	52	2.6	78	5.3	157	6.1	196	7.9	235	9.3	274	10.6	313
12	2.4	70	3.6	104	7.1	209	8.8	261	10.6	313	12.3	365	14.1	418
15	2.9	87	4.4	131	8.8	261	11.1	326	13.2	391	15.4	457	17.6	522
20	3.9	116	5.9	174	11.8	348	14.7	435	17.6	522	20.6	609	23.5	696

TABLE 2-12. FERTILIZER APPLICATION RATE TABLE

Rate (lb/acre)	Pounds per 100 Feet of Row				
	24-inch Rows	30-inch Rows	36-inch Rows	42-Inch Rows	48-Inch Rows
100	0.5	0.6	0.7	0.8	0.9
200	0.9	1.1	1.4	1.6	1.8
300	1.4	1.7	2.1	2.4	2.8
400	1.8	2.2	2.8	3.2	3.7
500	2.3	2.8	3.4	4.0	4.6
600	2.8	3.4	4.1	4.8	5.5
700	3.2	3.9	4.8	5.6	6.4
800	3.7	4.5	5.5	6.4	7.3
900	4.1	5.1	6.2	7.2	8.8
1,000	4.6	5.6	6.9	8.0	9.2
1,100	5.1	6.2	7.6	8.8	10.1
1,200	5.5	6.7	8.3	9.6	11.0
1,300	6.0	7.3	9.0	10.4	11.9
1,400	6.4	8.0	9.6	11.2	12.6
1,500	6.9	8.6	10.3	12.1	13.8

TABLE 2-13. GRANULAR APPLICATION RATE TABLE

Rate (lb/acre)	Grams Per 100 Feet of Row				
	24-in. rows	30-in. rows	36-in. rows	42-in. rows	48-in. rows
5	10	13	16	18	21
6	13	16	19	22	25
7	15	18	22	26	29
8	17	21	25	29	33
9	19	23	28	33	38
10	21	26	31	36	42
12	25	31	37	44	50
15	31	39	47	55	62
20	42	52	62	73	83
25	52	65	78	91	104
30	63	78	93	109	125
40	83	104	125	146	167
50	104	130	156	182	208
60	125	156	187	218	250
75	156	195	234	273	312

TABLE 2-14. DISTANCE TO COVER FOR EACH NOZZLE TO SPRAY 1/128TH ACRE

Average Nozzle Spacing (inches)	Distance to Cover (feet)
6	681
8	510
10	408
12	340
14	292
16	255
18	227
20	204
22	186
24	170
30	136
36	113
38	107
40	102
42	97
48	85

Note: Each oz per nozzle represents 1 gal per acre application rate.