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PERFORMANCE OF DRY FERTILIZER APPLICATORS

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In the late 1940s bulk blending of granular fertilizer became a common practice in the United States. Custom bulk spreading soon became a thriving industry. The kingpin of the custom applicator fleet was the spinner spreader truck, and rightly so. No other applicator, as easy to maintain, could cover as many acres as rapidly as could the spinner spreader. The simplicity and speed of these machines have contributed to their popularity despite their tendency to cause streaking in fields from nonuniform application. This problem has created a marketing tool for the liquid fertilizer dealer. In the past 5 years, however, equipment manufacturers have developed machines which supposedly can apply dry fertilizer with the accuracy and uniformity of liquid sprayers.

Commonly referred to as boomed dry spreaders, these applicators belong to one of two classes--pneumatic or auger-type. These machines are more expensive than spinner spreaders. The question is: Are they worth the extra cost? This paper presents some data on the performance of boomed and spinner spreaders. No attempt will be made to rate these machines because economic factors required for such ratings are beyond the scope of this paper. A rating also depends on the importance assigned to particular aspects of performance, such as uniformity, rate accuracy, range of application rates, ease of rate adjustment and calibration, and nutrient application uniformity of blends. The data in this paper verifies that no applicator is superior in every aspect of performance.

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Machine Designs

In double spinner spreaders, material is metered volumetrically by an apron which conveys fertilizer from the hopper through an adjustable opening. Ground-speed coordination of metering is done mechanically or hydraulically. A flow-dividing chute directs the flow of fertilizer onto two spinning discs (or fans). The position of chute, location of blades on the discs, speed of rotation of the discs, and physical properties of the fertilizer all influence the spread pattern from double spinner applicators.

Four pneumatic dry spreaders are being marketed in the United States for the custom applicator. A fifth pneumatic machine designed for retro-fitting on existing dry spreaders is also available. Basic to all the pneumatic applicators is the use of venturis to introduce fertilizer into the airstreams in the lines which feed the outlets. Mechanisms for dividing the flow of material before being introduced into the airstreams differ. Three machines use a slotted chute beneath the supply apron to divide the flow of fertilizer. One machine has equal-width vane type rollers in the bottom of the hopper. Data presented in this paper is from a machine that uses a vertical auger to deliver fertilizer to a circular distributor. Fertilizer is metered volumetrically with an apron as in spinner spreaders.

Two auger spreaders are available. One is a truck unit used primarily in the Northwest; the other is offered nationwide on a high flotation rig. The distribution systems are similar. Augers deliver fertilizer to booms. An auger in each boom keeps the booms full during application and a screw in the bottom of each boom meters fertilizer out of equally spaced holes. Application rate is controlled by varying the speed of the metering screw.

Performance Tests

Data presented in this paper is based on tests made by TVA. Though the machines were not evaluated in side-by-side tests, fertilizers and procedures used were similar. Procedures had to be altered for some tests to obtain reliable data. These procedures and any equipment required to follow them are described.

Spread Patterns

Spreader clinics have been conducted by TVA in 14 states. In these clinics one to several spinner applicators, usually double spinner trucks, were spread tested. A pattern from a single pass of the applicator was measured in louvered pans spaced 10 feet apart. The pattern was graphically or mathematically superimposed upon itself to simulate overlap at different driving intervals. After overlapping the pattern, the coefficient of variation (CV) was calculated. The CV is the standard deviation of points that make up the overlapped spread pattern curve divided by the mean and multiplied by 100. The Prairie Agricultural Machinery Institute, Lethbridge, Alberta, which tests most applicators sold in Canada, considers CV's of 15% or less to be acceptable. A perfect pattern has a CV of 0%. In TVA spread pattern testing, double spinners have produced patterns with CV's ranging from 6 to 50%. Usually, poor patterns are corrected by adjusting the delivery chute. Occasionally, excessive spinner speed causes the poor pattern and this is easily corrected. When fertilizer used is of good quality, neither wet nor high in fines content, a double spinner spreader can usually be adjusted to produce a pattern with a CV below 20%.

Initial spread pattern tests of a pneumatic spreader did not produce reliable data because a considerable amount of fertilizer ricocheted out of collection pans. In subsequent spread tests fertilizer was collected between strips of lumber while the vehicle was kept stationary. All the material broadcasted was retrieved. A spread pattern from a pneumatic spreader is shown in figure 1. The CV of this pattern overlapped at a 50-foot driving interval is 10.8%. This spreader had 20 outlets spaced 30 inches apart.

The results of a spread test from an auger spreader is shown in figure 2. As in the pneumatic spread test, strips of lumber were used to form collection areas 30 inches wide. The CV for this pattern is 6.0%. This machine had 100 outlets spaced 6 inches apart.

Rate Accuracy

The rate of application from spinner spreaders is difficult to measure. Many computer programs being used to analyze spread patterns calculate rates of application. These programs assume that no fertilizer ricochets out of collection pans. Preliminary tests by TVA indicate that this method of determining rates of application can yield values lower than actual application rates (Broder 1983). The most accurate method of determining application rates from spinner spreaders is to weigh the applicator before and after applying fertilizer over a known area. In one

FIGURE 1
SPREAD PATTERN
PNEUMATIC SPREADER

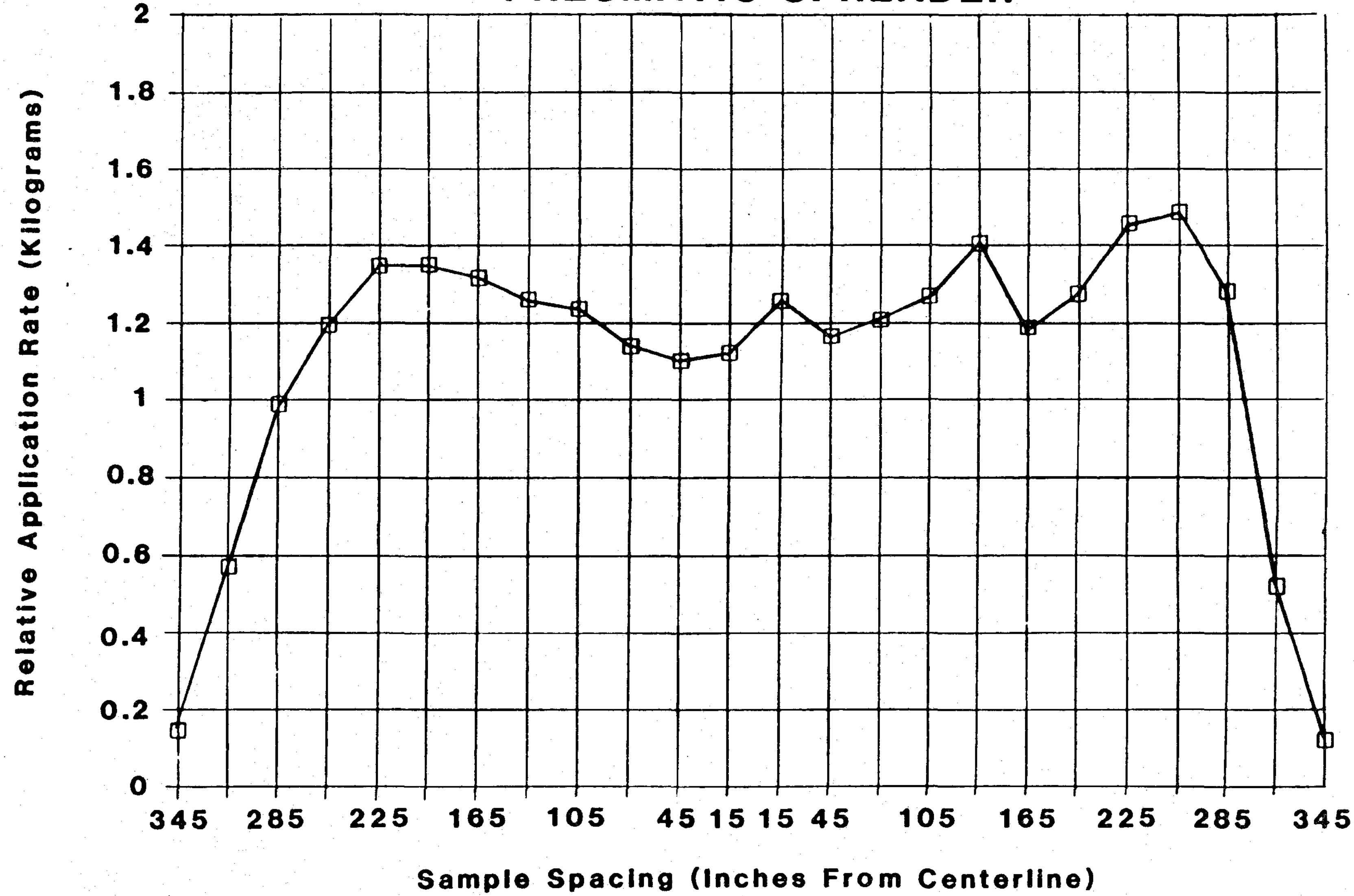


FIGURE 2

SPREAD PATTERN OF AUGER SPREADER

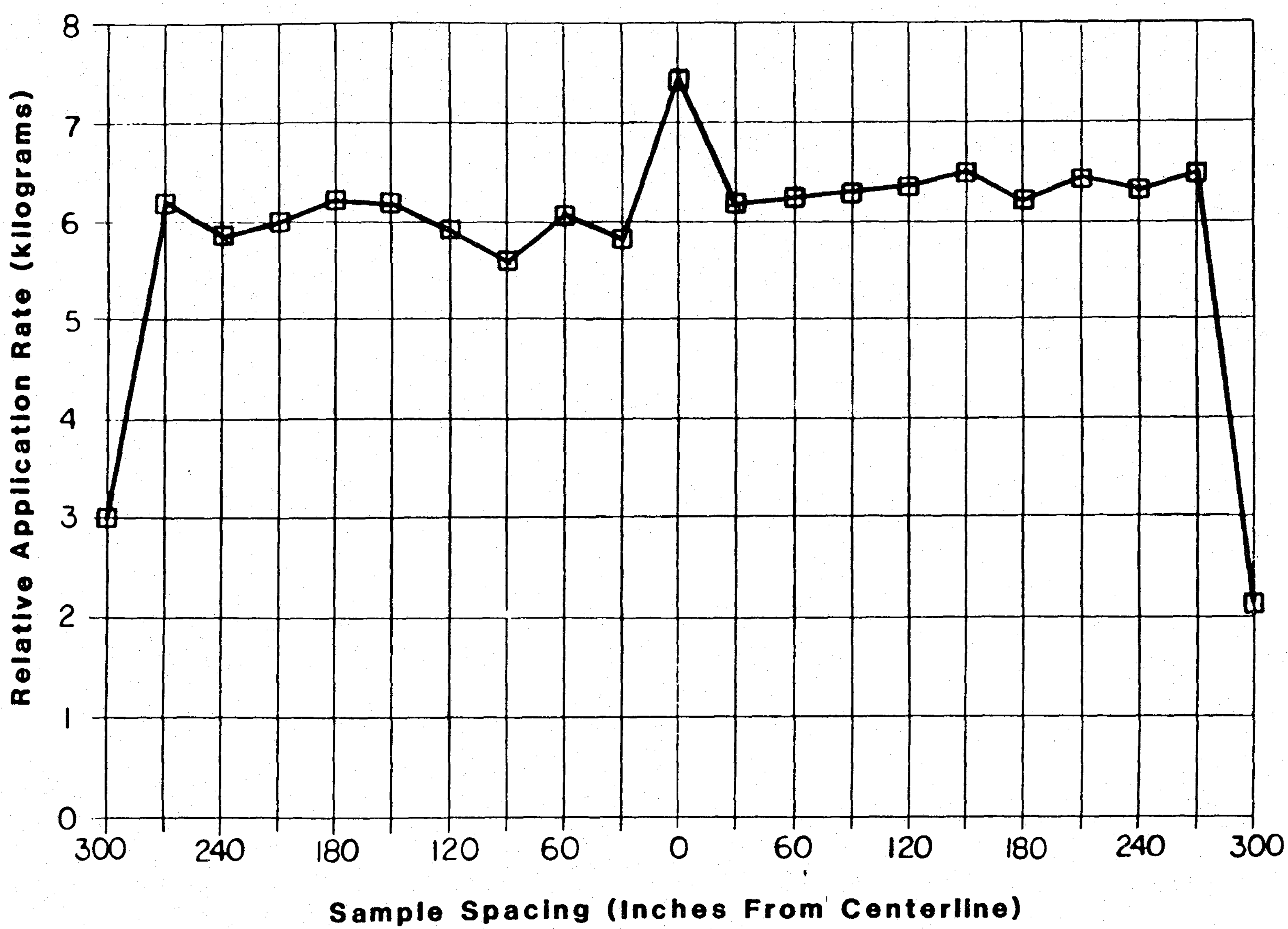


FIGURE 3

NUTRIENT DISTRIBUTION OF POOR BLEND FROM DOUBLE SPINNER SPREADER

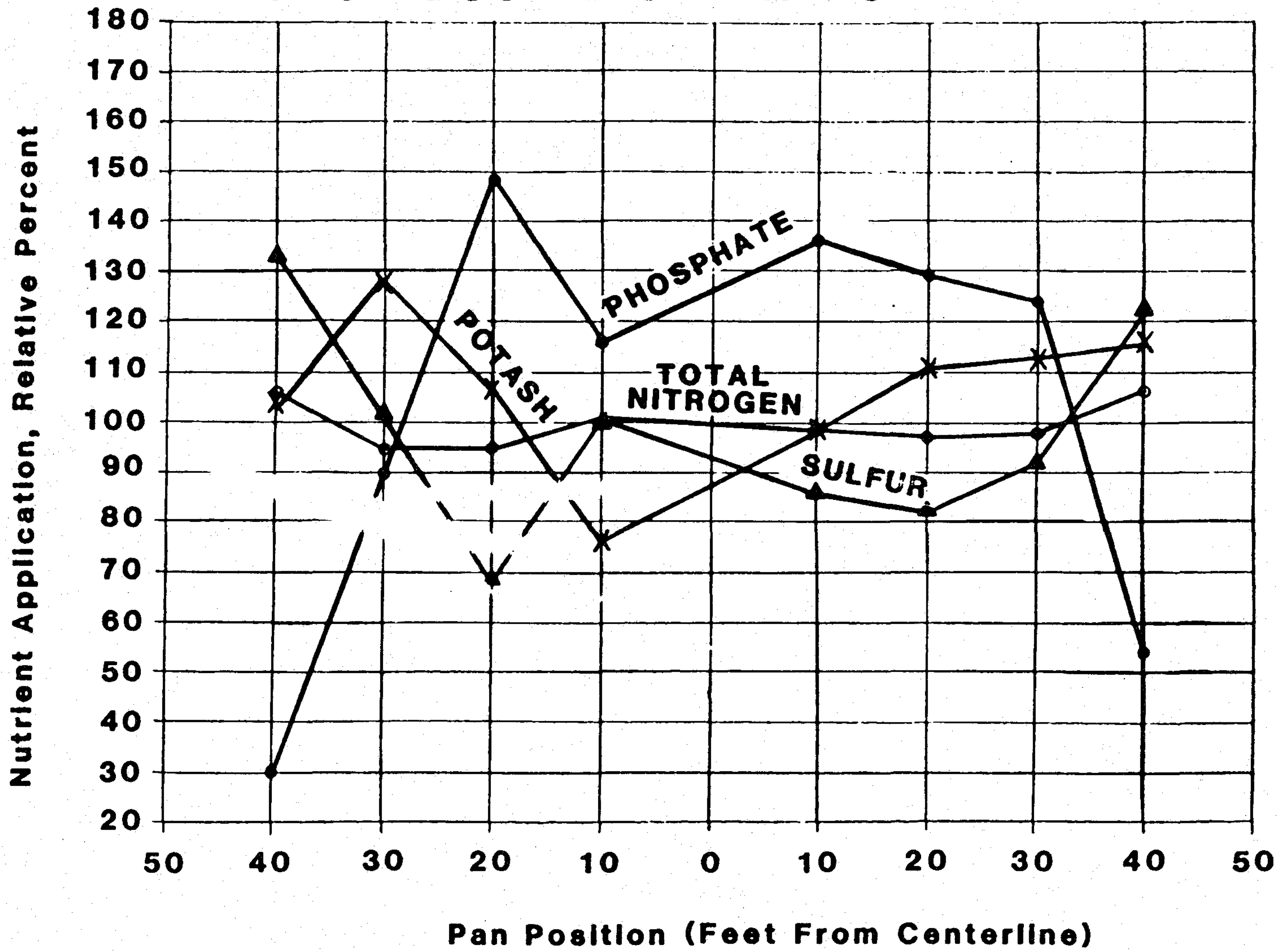


FIGURE 4

NUTRIENT DISTRIBUTION OF GOOD BLEND FROM DOUBLE SPINNER SPREADER

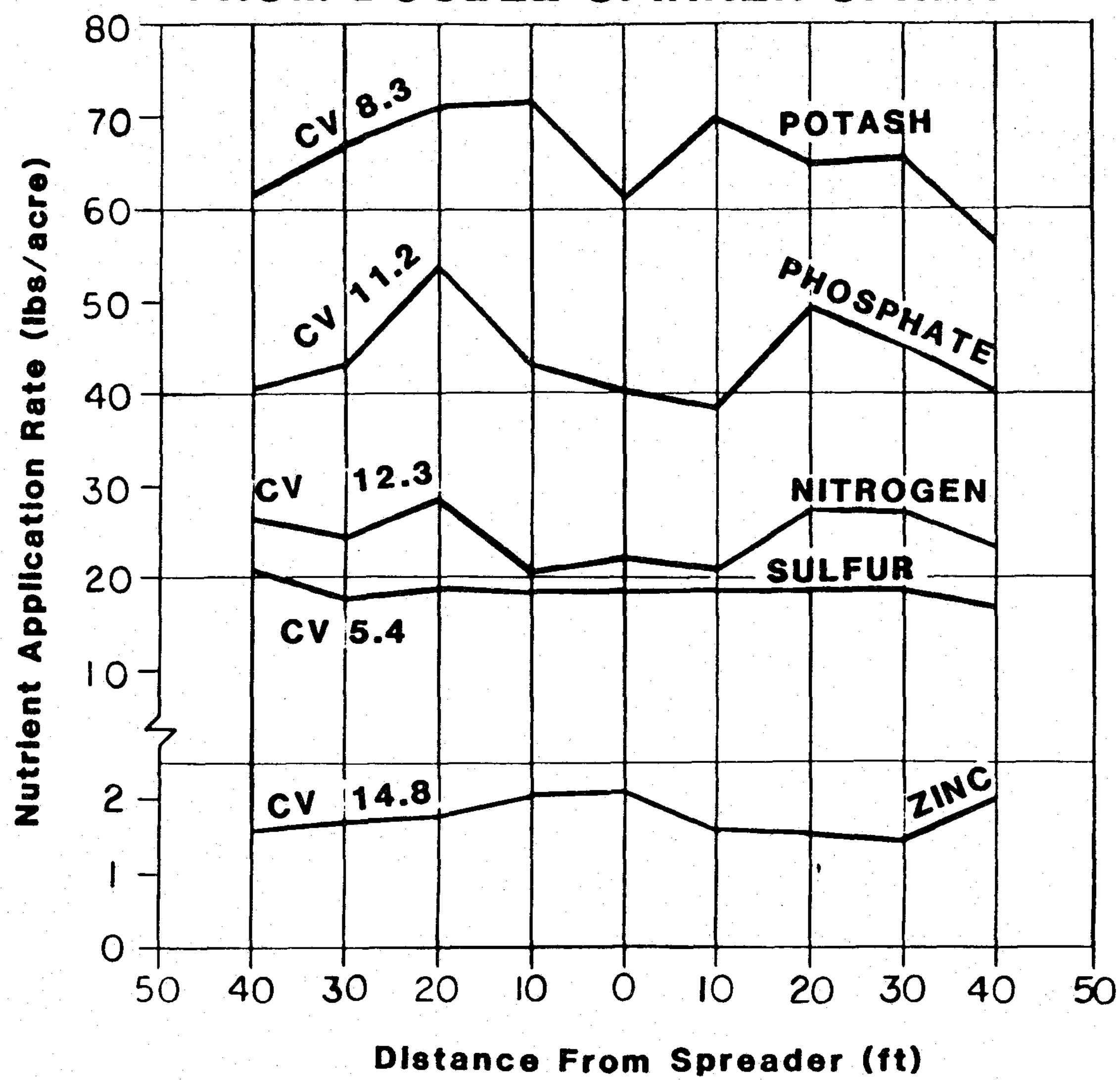
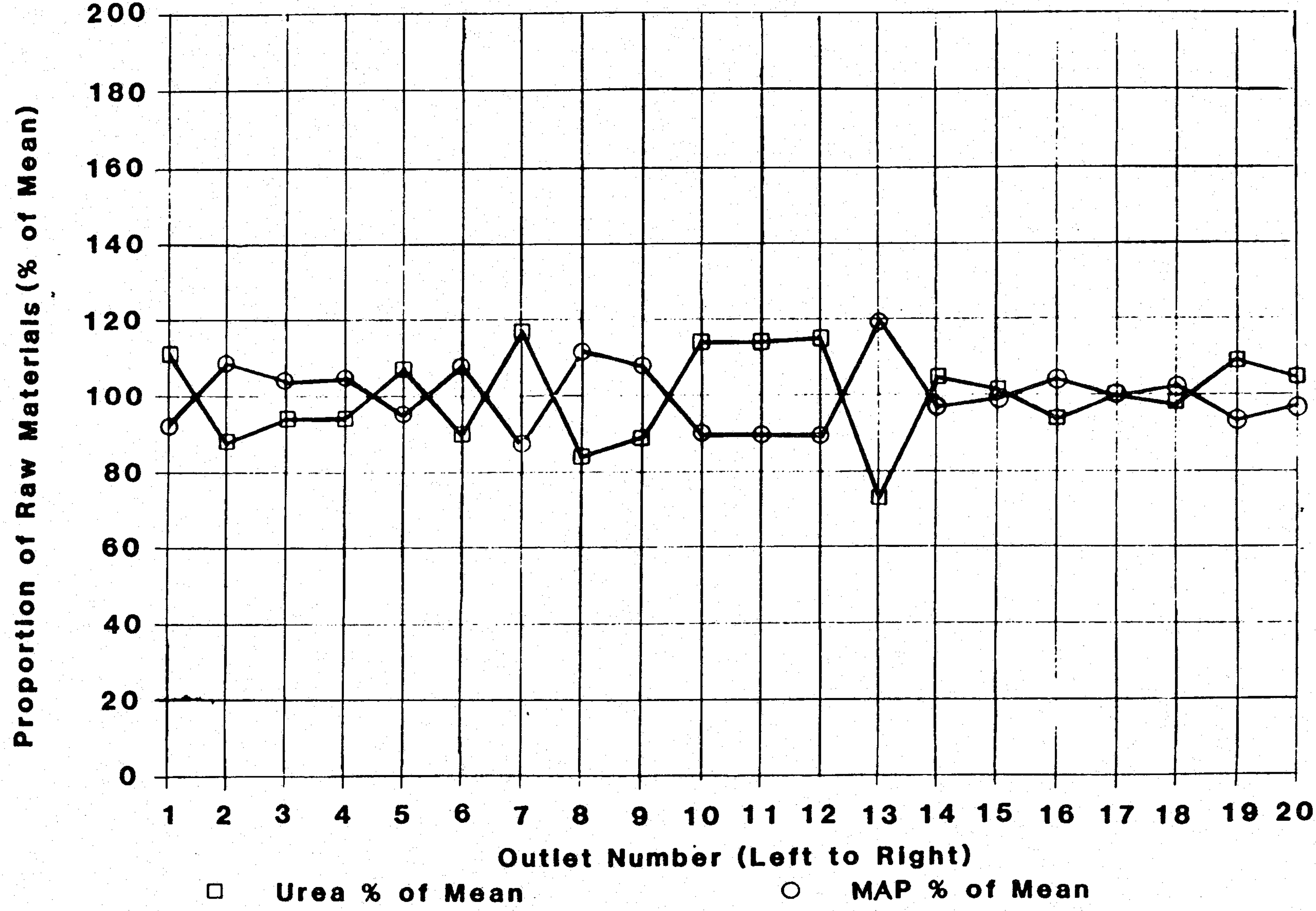


FIGURE 5

NUTRIENT DISTRIBUTION OF BLEND FROM PNEUMATIC SPREADER



such rate test a spinner spreader delivered the exact desired rate of 300 pounds per acre. Other tests, however, have yielded rate errors as high as 45% (Broder 1983).

There are many causes for rate errors from spinner spreaders. Operators often drive at an interval different from that on which the rate chart is based. Incorrect bulk densities are often used to choose gate settings. Rubber seals on the bottom of gates become worn or torn, which changes the size of the opening. The scale or pointer used to set the gate height is often bent or welded in the wrong place. The material being applied must be free flowing for belt meters to be accurate. Tests reported in 1930 showed that when free flowing fertilizer was used, the height of fertilizer in the hopper had little effect on the discharge rate of belt metering systems (Kepner et al. 1972). Fertilizer that was not free flowing (angle of repose greater than 55 degrees) could not be metered accurately with most types of equipment. The point is that belt metering systems are reasonably accurate. The physical characteristics of fertilizers have a slight influence on metering rate. Well rounded urea, for example, will flow from a belt feeder at a higher rate than will coarse potash. The poor results obtained in tests were a result of poor calibration, lack of maintenance, poor fertilizer quality, or incorrect setup of the spreader.

Pneumatic spreaders tested by TVA had belt metering systems. One machine yielded rates that were consistently 25 to 30% below the desired rate; the other machine produced rates 10% higher than the preselected rate. These errors were a result of poor calibration data. An accurate verification of applicator output for a given rate setting could have been used to correct the error.

The auger applicator has metering screws which rotate at a speed proportional to vehicle speed. Rate calibrations are recommended for fine tuning the rate settings to compensate for variations in metering due to particular flow characteristics of fertilizers. In eight calibrations of the auger spreader, rates were within 7.7% of the preselected rate.

Effect of Speed on Rate Accuracy

Limited work has been done to determine the effect of speed on application rate of spinner spreaders. Operators familiar with electronic rate controllers realize that excessive vehicle speed can cause rate errors from hydraulically driven belt feeders. Electronic rate controllers have an alarm which sounds when vehicle speed exceeds the capacity of the hydraulic system to maintain the belt speed proportional to vehicle speed. Belt feeders on many truck applicators are hydraulically driven. All these machines are subject to application error at high speeds. In a test conducted in Kansas to verify this, the application rate decreased from 100 pounds per acre to 50 pounds per acre when the applicator speed reached 22 miles per hour.

Some pneumatic applicators are subject to application rate errors during speed changes. This problem is inherent to the design of the applicator and stems from the fact that the distribution system is attached to and downstream from the metering system. In the first pneumatic applicator tested by TVA the fertilizer was metered from a belt. The fertilizer was then augered horizontally to a vertical auger which elevated the fertilizer and distributed the fertilizer to several outlets. About 6 seconds was required for material being metered through the gate to reach the ground. Tests revealed that the machine overapplied fertilizer when decelerating and underapplied material when accelerating. This lag was reduced to 2 seconds in the new version of the pneumatic applicator. Errors in application rate from lags in metering response can be eliminated by avoiding abrupt changes in applicator speed.

The auger applicator meters fertilizer by a screw in the bottom of each boom. Since the material exits the boom immediately after being metered, there is no lag in metering response. In tests to verify this, variation in rate from rapid acceleration or deceleration was about 5%.

Spreading Blends-Segregation Tendencies of Applicators

Many believe that fertilizer particle density as well as particle size affect the trajectories (distance that a granule will travel from spinners before reaching the ground) of fertilizer granules. Research reported in 1964 (Hoffmeister, et al.) showed that particle size had the greatest effect on the trajectories of fertilizer particles. Particle density and shape had very little effect on the distance that granules traveled from spinners. This result was not surprising considering that increasing particle size from 16- to 6-mesh (1.19 to 3.35 mm) corresponds to a twentyfold increase in weight, whereas the usual range of particle density can cause no more than a twofold increase in particle weight. In spread pattern testing the relative distance that different size particles travel from the applicator is easily seen by inspecting the size of particles in collection pans. The smallest particles are caught in the pan directly beneath the spreader. This separation of broadcasted fertilizer by size is called ballistic segregation. When all the fine particles in a blend are from one raw material, an excessive amount of the nutrient contained in this raw material will be applied near the applicator tracks.

Figure 3 shows the nutrient distribution from a spinner spreader applying a poor blend. Samples from a single pass of the applicator were analyzed for the nutrients shown in figure 3. The ammonia nitrogen in this blend was contained in diammonium phosphate (DAP). The sulfur was in forestry size sulfur-coated urea (SCU). The other materials in the blend were granular urea and granular potash. The median particle sizes of the DAP, potash, urea, and SCU were, respectively, 1.60, 2.55, 2.32, and 4.20 millimeters. Ballistic segregation caused an excessive amount of the small DAP to land near the spreader while more of the large SCU traveled to the outer edges of the pattern. Samples from this blend were analyzed to determine the nutrient distribution while driving at a 50-foot interval. The CV's of phosphate, sulfur, and potash were, respectively, 32.6, 42, and 33.4%. Total nitrogen application was uniform. The CV was 11.8%. The use of three raw materials containing nitrogen--SCU, DAP, and urea--attributed to this uniform nitrogen application. These materials ranged in size from the smallest to largest material in the blend.

Figure 4 has plots of nutrient distribution from a good blend. This blend contained granular ammonium sulfate, DAP, potash, and a homogeneous granular product, 0-7-21 grade containing sulfur, zinc, magnesium, manganese, and boron. All components in the blend were well matched in size. Despite differences in particle weight, the spreader uniformly applied all the nutrients in the blend. In this test the CV's of all the nutrients for which samples were analyzed were below 15%.

In testing the segregation tendencies of boomed spreaders, a blend of two materials poorly matched in size was used. A poor blend was necessary since data had shown that nutrients in a good blend could be uniformly applied with a spinner spreader. With two raw materials only one nutrient had to be analyzed to determine the composition of each sample. The blend used in boom spreaders was about half forestry-size urea and half mono-ammonium phosphate (MAP). The median particle sizes of the urea and MAP were, respectively, 4.2 and 2.2 millimeters. This extreme variation in particle size was more severe than normal, but was used to determine if boomed applicators could avoid segregating a blend that would surely segregate from ballistic action with a spinner spreader. The proportion of these two raw materials in samples collected beneath each outlet of the pneumatic spreader is shown in figure 5. Samples from all but one outlet were within 15% of the average analysis. The CV's of urea and MAP distribution were, respectively, 11.8 and 8.7%.

The same blend was applied through the auger spreader; however, material from every fifth outlet on one boom was analyzed. This yielded 11 samples. Segregation was detected from chemical analyses of the samples. A higher proportion of MAP exited the boom nearer the applicator centerline and a higher proportion of the large urea exited the machine near the outer end of the boom. This type of segregation was expected because of the rolling action of the blend in the boom. When fertilizer rolls down the slope of a pile, the smaller particles are trapped near the top of the pile while larger particles travel to the outside. In a stationary pile this results in a higher concentration of small particles in the center of the pile. In the boom of the auger spreader, this deposition by size would cause the larger material to travel farther in the boom than the smaller particles before exiting.

Results of these tests are not conclusive and are not presented because a considerable amount of segregation of the blend occurred before and during transfer of the blend to the applicator hopper. Determining the amount of segregation caused by the applicator was impossible because the analysis of the blend varied while the boom was being filled. The MAP, being the smaller ingredient, was in the center of the pile in the hopper and, therefore, was delivered to the boom before the large urea which was concentrated on the outer edges of the pile. Further testing of the auger spreader is required to determine the segregation tendencies of the auger applicator.

Ease of Calibration

Calibration is the verification of application rates by measuring applicator output at known settings. The most accurate method for calibrating most applicators is to weigh the applicator before and after applying fertilizer over a known area. This is a time-consuming operation that is only practical for checking the applicator at one particular rate setting with one material. Computer programs being used to analyze spread patterns calculate application rates based on the size of collection pans and the amount of material they collect. The design of most collection pans is such that a considerable amount of fertilizer that enters the pans bounces out. Consequently, computer programs are used more to correct poor spread patterns than to verify application rates. Researchers are testing different collection pans to determine the best design for pattern testing as well as rate calibration. Unfortunately, spinner spreader manufacturers do not provide spread pattern test equipment with the applicators they sell. But some do sell the test equipment separately.

Application rate of the pneumatic spreader can be checked by attaching cloth bags to one or several outlets while driving a known distance. This technique was used by TVA engineers to measure the accuracy of rate settings. Neither the bags nor instructions for checking the pneumatic applicator output are provided by the manufacturer.

The auger spreader tested by TVA has a test pan that clips to the boom of the spreader. Instructions are given in the applicator owner's manual for conducting a rate calibration. The recommended procedure is to collect the flow from eight outlets in the pan while driving a distance of 218 feet. This distance is used because it corresponds to an area equal to 1/50th of an acre. The collected fertilizer is weighed on a sliding bar scale (also provided by the manufacturer) and multiplied by 50 to determine the machine's application rate. This procedure can be used to fine tune the machine's output to account for flow properties of different fertilizers.

Unique Capabilities of Boomed Spreaders

The data presented thus far illustrates one capability of boomed spreaders: Uniform broadcast application is achievable without spread pattern testing and adjustment. Though tests to ascertain the effects of wind on broadcast distribution of boomed spreaders have not been conducted, dealers using the boomed applicators claim the machines permit application of granular materials in higher winds. The auger spreaders and some pneumatic spreaders can apply fertilizer at half the normal spread width by switching off the supply of fertilizer to one boom. This is often desirable for fertilizing small areas and cannot be done with spinner spreaders.

Some fertilizer dealers have claimed that their boomed spreader permitted the application of finely sized fertilizer that could not have been adequately applied with a spinner spreader. Lumpy fertilizer and trash can create problems with boomed spreaders. In TVA tests of a pneumatic and auger spreader, paper entered the metering system and plugged an outlet. The overall spread pattern was not seriously affected. The plugging of adjacent outlets could cause areas in fields to receive no fertilizer. Another concern is metal or wooden objects. A tool or tree limb can cause considerable damage to a boomed spreader. Augers and housings on boomed spreaders are expensive to replace. A screen over the fertilizer hopper is an option available on one particular pneumatic spreader.

Though fine materials are no problem for boomed spreaders, wet fertilizers can be troublesome. One herbicide manufacturer has tested chemically impregnated fertilizer in boomed spreaders and has found that certain herbicide-fertilizer combinations are too sticky to apply without a drying agent. Humid weather, however, doesn't appear to be a major concern if the fertilizer is dry during filling. Tests with extremely hygroscopic fertilizer have been conducted at relative humidities above 90%. Using relatively dry fertilizer, caking was not a problem in either the pneumatic or auger spreader.

Some pneumatic spreaders have an upper rate limit that is somewhat less than that of spinner spreaders. Application rates about 1,000 pounds per acre and higher cannot be achieved with some pneumatic spreaders without reducing speed. This may present a problem when fertilizing certain crops. But the popularity of pneumatic machines stems from their ability to uniformly apply fertilizer at low rates or fertilizers impregnated with herbicides.

Boomed dry fertilizer spreaders have had a considerable impact on the dry spreader market. Many custom applicators charge a higher fee for application with a boomed spreader. Some dealers have only bought a boomed spreader because a competitor has penetrated their market with one. One dealer has said that the best advantage of the boomed spreader is that it helps sell fertilizer. The proliferation of new boomed spreaders in a depressed agricultural market indicates that there is a demand for improved application of dry fertilizer. Further refinement of equipment based on scientific testing should improve the quality of fertilizer application.

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