PERFORMANCE OF IN-CANOPY SPRINKLERS

by

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The goal of a center pivot sprinkler system is to uniformly distribute water on the soil surface. Uniform application and infiltration of irrigation water in the soil gives plants equal access to water. To reduce energy costs, center pivots have been converted from high pressure to medium and low pressure systems, while maintaining application uniformity. Design engineers and manufacturers have developed new sprinkler devices that operate at low pressures. These changes provide agricultural water users the opportunity to reduce pumping costs and insure an even distribution of water to all of their crop.

The new low pressure sprinkler devices have been designed to include tubing, called drops, that place the devices closer to the crop. Bringing the sprinkler device closer to the crop reduces water lost through evaporation and drift. In an attempt to reduce water loss even further, some producers are placing nozzles within the corn canopy. In-canopy sprinklers are viewed as very efficient because no water is seen above the canopy. Based on the assumption of improved water delivery, the trend has been too lower pressure and operate within the crop canopy to improve irrigation efficiency and reduce pumping costs. However, there are several factors that must be considered before adopting this change. Several basic questions remain:

1) How much water is lost to evaporation and drift when low pressure sprinkler devices are operated above the crop canopy as compared to within the canopy?

2) What happens to application uniformity when sprinklers are operated within the crop canopy?

3) What impact does the uniformity of in-canopy sprinklers have on the efficiency of water application?

Sprinkler water losses

Water loss from sprinkler devices can be categorized into to three main areas, air loss, canopy loss and ground loss. Water loss in the air occurs through evaporation or drift from the field. Loss of water in the canopy occurs through evaporation of water from the plant leaves. Some water is also intercepted and stored in the whorls of the plant and is evaporated at a later time. Ground losses occur through runoff and evaporation of water from the soil surface. Water stored on the soil surface and later infiltrated is not considered a loss if it remains near the point of application.

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Directly measuring the amount of water loss that occurs with sprinkler irrigation is difficult. Based on current and past research, researchers in Texas(Schneider and Howell, 1993) made comparisons among different sprinkler devices and height of sprinkler device with respect to the crop canopy. Their objective was to determine the amount of water loss that occurs above the canopy, within the canopy and from the soil surface. Table 1 gives the measured water loss and application efficiency for low angle impact sprinklers, spray heads, and Low Energy Precision Application (LEPA) sprinkler packages. Water losses and application efficiency are based on a daytime irrigation of 1-inch in corn with a full canopy.

Water Loss Component	Impact Sprinkler Water Loss	Spray Head Water Loss	LEPA Water Loss
Air Evaporation and Drift	0.03 in.	0.01 in.	0.00 in.
Net Canopy Evaporation	0.08 in.	0.03 in.	0.00 in.
Plant Interception	0.04 in.	0.04 in.	0.00 in.
Evaporation From Soil	Negligible	Negligible	0.02 in.
Total Water Loss	0.15 in.	0.08 in.	0.02 in.
Application Efficiency	85%	92%	98%

Table 1. Sprinkler water losses and application efficiency for 1-inch water application.

Based on their results and a review of other studies, these researchers concluded that converting from impact sprinklers to spray heads will improve application efficiency by approximately 5%. In converting from spray heads to a LEPA system, the application efficiency can increase by as much as 10%. The improvement in application efficiency occurs primarily as a result of the reduction of evaporation from the crop canopy. The amount of water lost between the sprinkler nozzle and the top of the crop canopy is quite small (only 3% for impact sprinklers). Therefore, less improvement can be made as a result of reducing losses in the air.

To realize the potential improvements in application efficiency using LEPA a complete LEPA system must be adopted. Air losses and canopy losses are eliminated because the LEPA devices are below the crop canopy. Surface storage created by specialized tillage equipment is required to prevent any runoff. LEPA application rates are more than the soil can immediately infiltrate.

Surface storage allows the water to pond temporarily until infiltration is complete. A reduction in soil evaporation is obtained by placing LEPA sprinklers in alternate rows. The crop must be planted in a circular pattern and drops spaced between every other row.

Converting from high pressure to low pressure is a method to reduce energy costs. Energy is not saved by simply moving spray heads into the crop canopy. Nor does lowering spray heads from just above the crop into the crop canopy make a LEPA system. Water losses were determined to be nearly the same for spray heads located just above the canopy and spray heads located within the canopy. This happens because as a pivot moves, drops are caught on the corn plants and the nozzles held at an angle. Water is sprayed on the entire canopy of the crop similar to if the spray head was located above the canopy. This occurs most frequently when corn is planted in straight rows under a center pivot.

An assumption made with the observations in Texas was that runoff was negligible. This can be assumed as long as infiltration is increased to meet the increased application rate or tillage is used to provide surface storage. If runoff does occur, the water lost due to runoff will further reduce the water application efficiency. Runoff can occur for a number of reasons and under different conditions.

Variability of In-Canopy Application

The diameter of coverage can be defined as the circular area that is wetted by a sprinkler. The wetted diameter is determined by the operating pressure of the irrigation system and the sprinkler device selected. Lower operating pressure normally means a smaller wetted diameter. Reducing the wetted diameter can increase the potential for runoff from a center pivot irrigation system by increasing the peak and average water application rate. Sprinkler devices placed on drops within the crop canopy will result in a reduction of the wetted diameter. The reduction in wetted diameter occurs due to the water droplets hitting the leaves of the crop before reaching their designed distance of throw.

Water distribution when using in-canopy sprinkler devices has been a research topic in both Kansas and Nebraska. In a Kansas study, Lamm (1995) determined the coefficient of uniformity for different nozzle spacings and crop row orientation. The coefficient of uniformity is a measure of how evenly water is distributed over the irrigation application area. Figure 1 shows the results of six nozzle spacings for spray heads located 12 in. above the ground. The corn was planted both parallel and perpendicular to the sprinkler line of travel. As shown in the figure, as nozzle spacing increases, the coefficient of uniformity decreases.

The parallel row orientation, simulating a crop planted in a circle, had uniformity coefficients of 70 or more for spacings up to 10 ft. However, based on technology today, the 5 ft spacing with parallel row orientation is only marginally acceptable. When corn was planted in straight rows, the center pivot applied water perpendicular to the rows and the coefficient of uniformity was reduced even further for all nozzle spacings. This row orientation would simulate the majority of a field when the corn was planted in straight rows. For 7.5 and 10 ft spacings, the coefficient of uniformity was between 50 - 60%. The uniformity coefficient usually exceeds 90 for center pivots with devices placed above the crop canopy, and located at design spacing.

In a Nebraska study soil water content was measured as a method to evaluate the uniformity of water distribution. Soil water content was measured in the top 12 in. of soil before and after irrigation. Spinners[1] were spaced 12.5 ft apart and located at a height of 42 inches in a mature corn crop. Sprinklers were moving parallel to the corn rows but not necessarily between the corn rows. Figure 2 shows the location of the sprinklers in the corn rows and the change in soil water content measured before and after irrigation. Soil water content increased approximately 10% in the rows nearest the sprinkler device. Soil water content had no change or increased only at locations directly between the sprinkler devices. The small change in soil water content indicates the rows between the sprinkler devices received little or no water during the irrigation event.

Both of these studies demonstrate the variability in water application as a result of in-canopy irrigation. Poor uniformity results regardless of nozzle spacing or nozzle height. However, poor uniformity may or may not influence crop yield. Soil has the ability to redistribute water applied by a sprinkler to the plants much like furrow irrigation when water is applied in every other furrow. However, the water application pattern shown in Figure 2 could not be redistributed to result in uniform water distribution.

Sprinkler spacings greater than 10 ft are not recommended for in-canopy irrigation of corn because low water application occurs between the sprinkler devices and the soil cannot move the water far enough or fast enough to meet crop demand. Water application nearest the sprinkler device is of more concern because of the high application rates due to crop interference. Without adequate surface storage or improved infiltration, the result of higher application rates will be runoff.

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[1]Mention of trade name is for information only and does not imply endorsement

Water Application Efficiency

If a system is designed properly, the application rate should be less than the soil infiltration rate otherwise surface storage must be provided. When the sprinkler is located above the crop canopy, uniformity is good and the water application rate is as designed, Figure 3a. As the system travels over a given point, the application rate increases with time for half of the application period then decreases. Also, given in Figure 3a is an infiltration rate curve. If the application rate of the irrigation system exceeds the infiltration rate of the soil, surface ponding or runoff will begin. Adequate storage on the soil surface will allow water to pond until infiltration is completed. If, however, the application rate exceeds both the infiltration rate and surface storage capacity, runoff will result and reduce application efficiency and uniformity.

Figure 3b shows the same irrigation system applying the same amount of water but with the sprinkler located in the crop canopy. The application pattern is distorted and narrowed due to the interference of the crop canopy. When operating within the crop canopy the same amount of water is applied but the application rate is increased because the time of application is shorter. This results in an increase in the amount of potential runoff for a given system. Infiltration rate varies with soil type. The potential for runoff may be reduced if infiltration rate or surface storage is increased.

As wetted diameter is reduced, either by sprinkler design or by crop interference, the application rate increases and the potential for runoff is increased. In a second Nebraska study, runoff was measured from three different sprinkler devices; a LEPA system, Spinners located 42 in. Above the ground and Spinners located above the crop canopy. To evaluate the impact of surface storage, each plot was divided into normal cultivation and furrow diking. Field slope varied between 1 - 3%. The systems were evaluated two different times and the results are shown in figures 4 and 5. The LEPA system resulted in over 15 - 25% runoff from both irrigation events. The spinners located at 42 in. height had runoff of between 10 - 15%. With some surface storage capacity, using furrow diking, runoff from the spinners at truss rod height was lowest at approximately 8%.

The 8% runoff for the Spinners above the canopy in Figure 5. reflects approximately 0.15 in. of runoff during a 0.7 in. irrigation. Locating the Spinners at a 42 in. height increased runoff to a total of approximately 0.35 in. The savings we can expect based on the Texas information is 1-2% moving from above to within the crop canopy. A 2% savings in a 0.7 in. irrigation is 0.01 in. The result of placing the sprinkler devices in the canopy was a savings in water of 0.01 in., but an increase in runoff of 0.2 in.

The same can be said for LEPA where a 10% savings is expected when moving from sprinkler devices above the canopy to a LEPA system. A 12% savings for a 0.7 in. irrigation is 0.08 in. Runoff increased by over 0.25 in. from above the canopy to the LEPA system. The result is 0.17 in. of water to runoff using the LEPA system.

Summary

For the soil and slope in this study, none of the devices in the Nebraska study would be acceptable. Water application rates must be decreased to match infiltration rates of the soil. However, these low applications would not be acceptable. With the Spinners above the canopy, water application could be reduced to approximately 0.5 in. to reduce the potential for any runoff. With the LEPA system water application would have to be decreased by over half, resulting in a 0.3 in. application. The efficiency of irrigation is reduced when applications are in this range due to the increase in the number of irrigations and the subsequent increase in evaporation from the soil and plant canopy.

Other soils having a different slope and intake rate will give different runoff results. The gains made through improved sprinkler devices and reduced operating pressure can be quickly over shadowed by runoff losses. Runoff when not kept at a minimum will result in increased pumping costs and/or crop water stress. As the use of low pressure and drops are evaluated, ask yourself a basic question. Will the change I make result in runoff? If the answer is yes, determine how you can overcome the problem before changes to the system are made. The system you currently have may provide the most efficient application of water.

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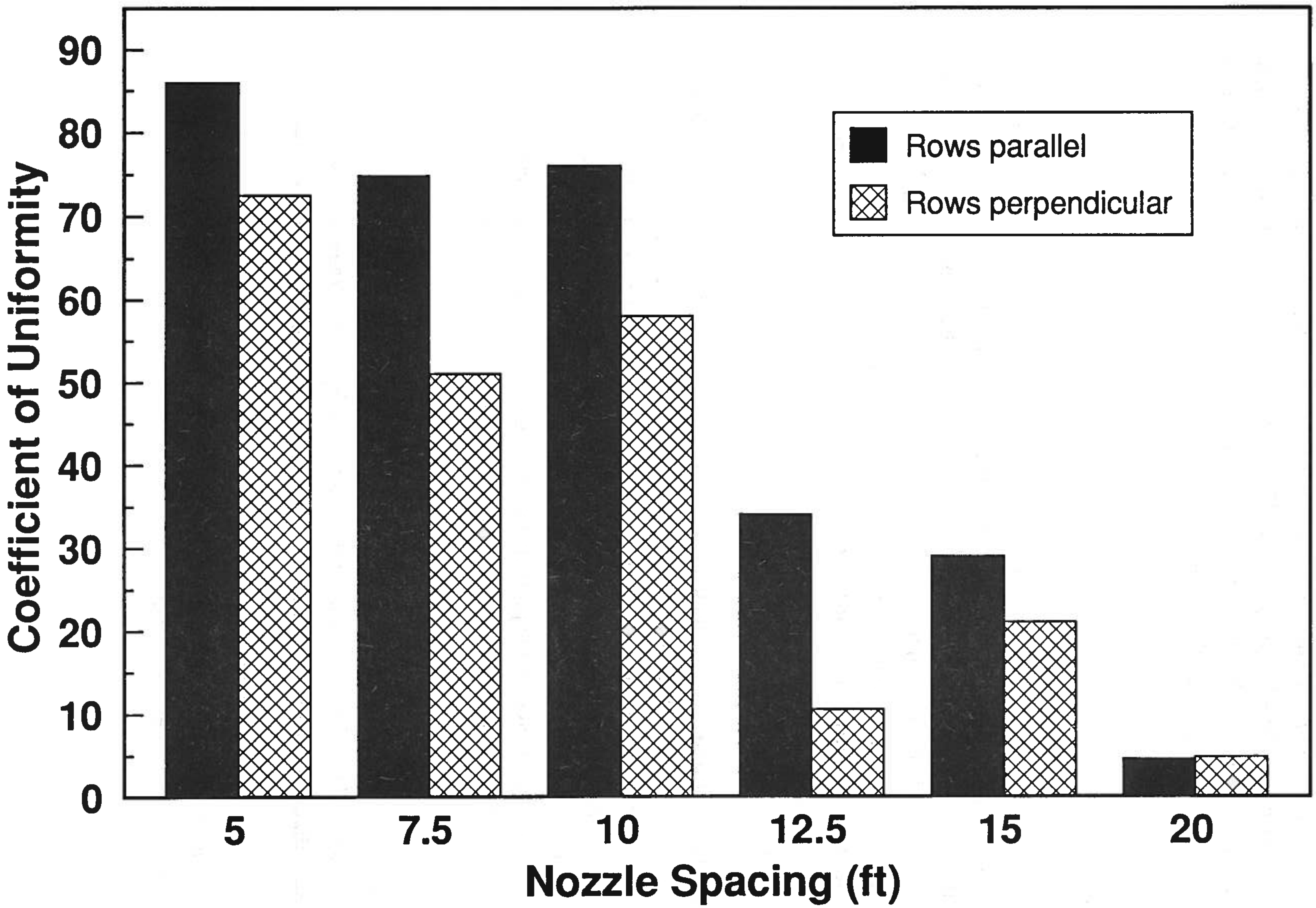

Figure 1. Uniformity coefficient for center pivot sprinkler using spray heads.

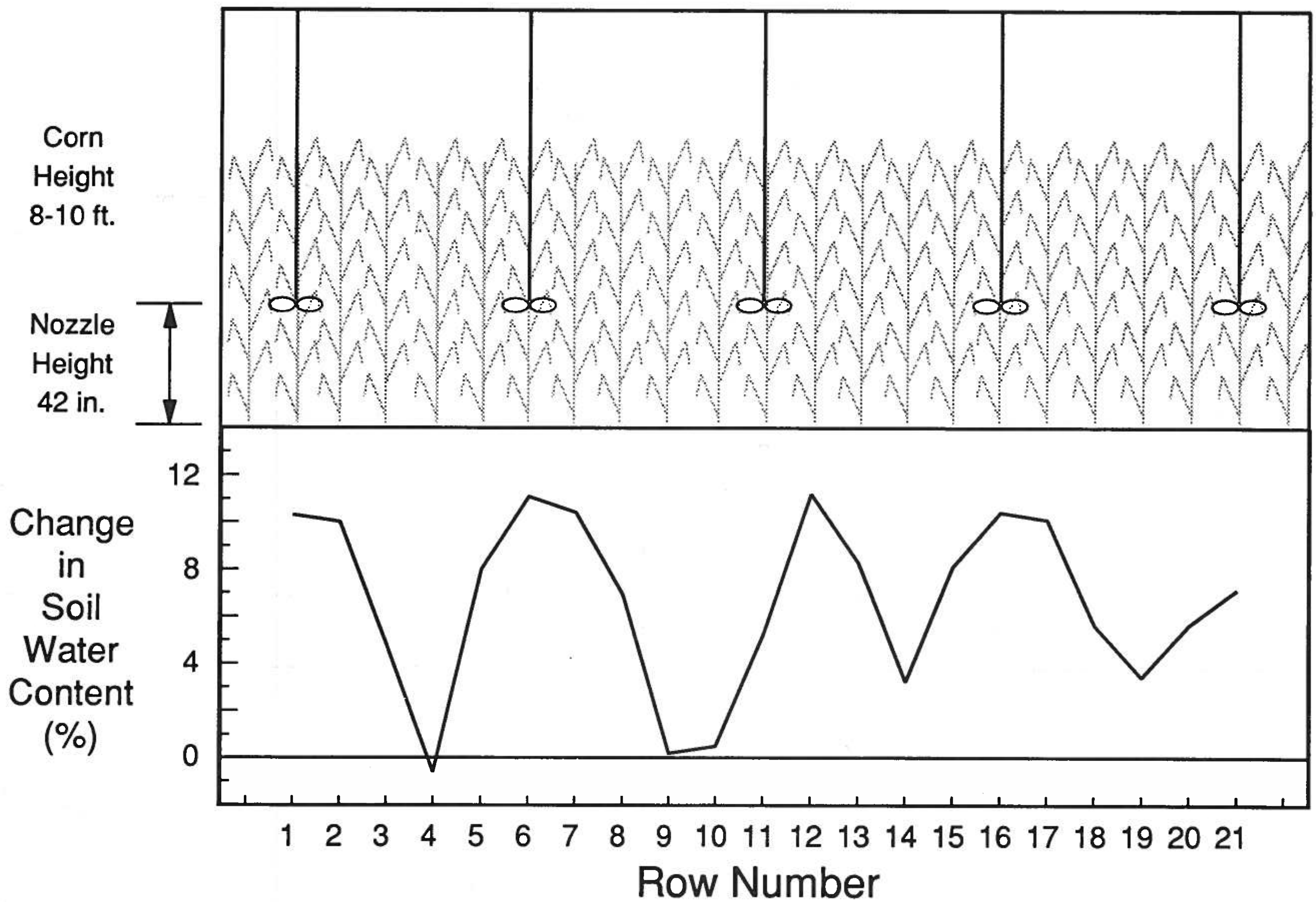

Figure 2. Change in soil moisture content before and after irrigation for spinners at 42 in. height and 12.5 ft. spacing.

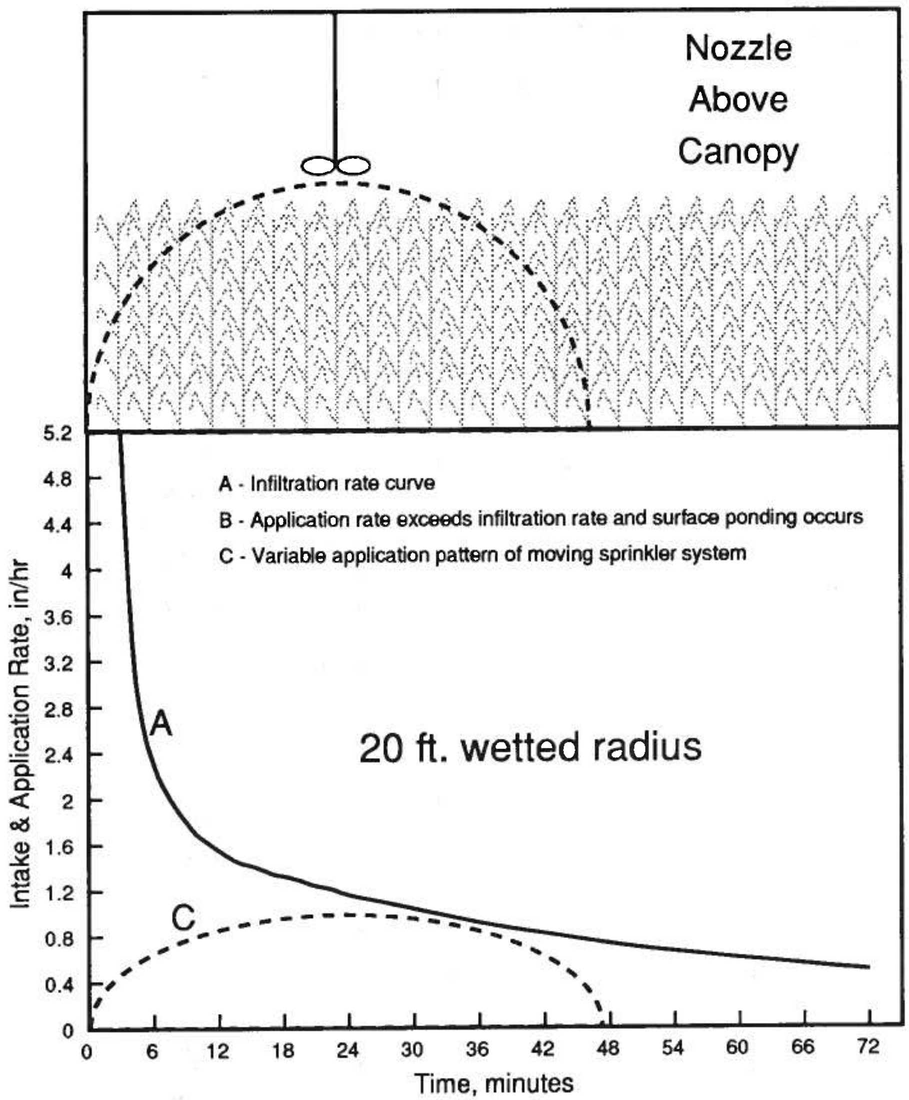

Figure 3a. Potenial runoff for nozzle located above crop canopy.

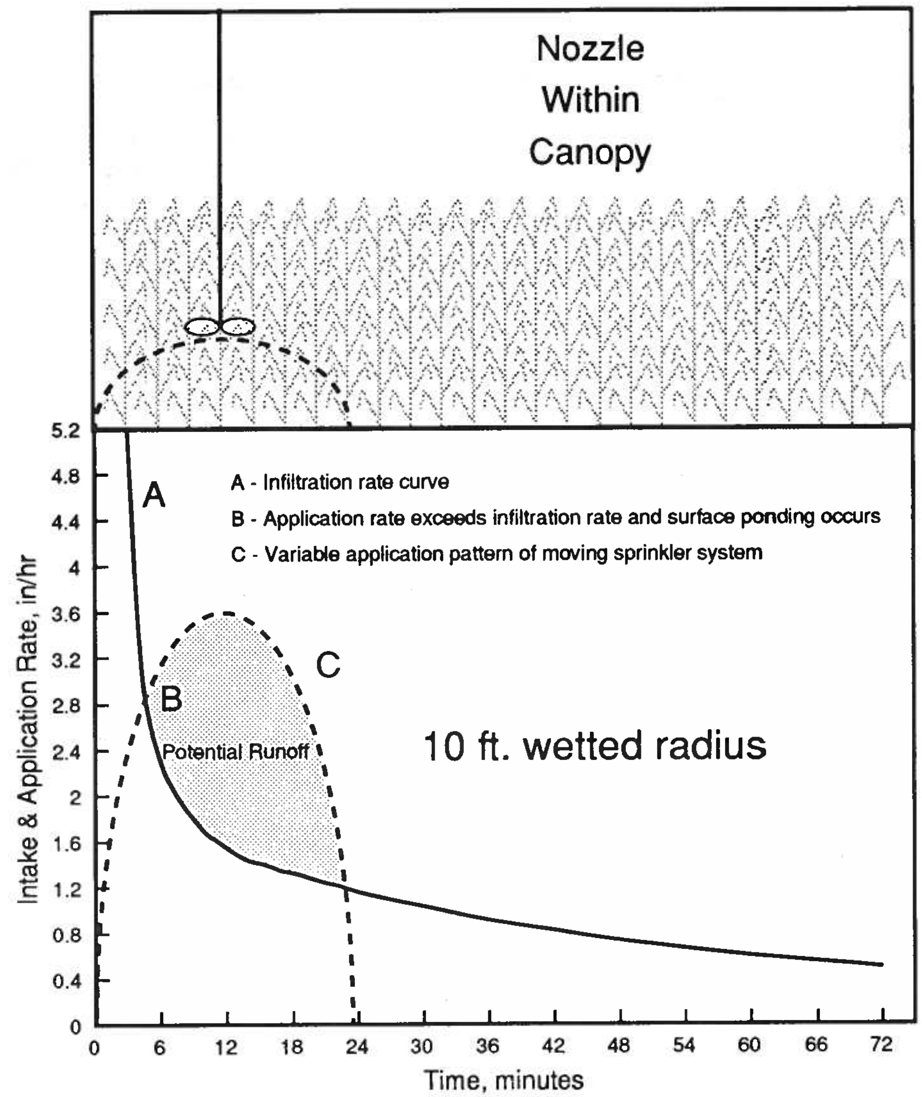

Figure 3b. Potential runoff for nozzle located within crop canopy.

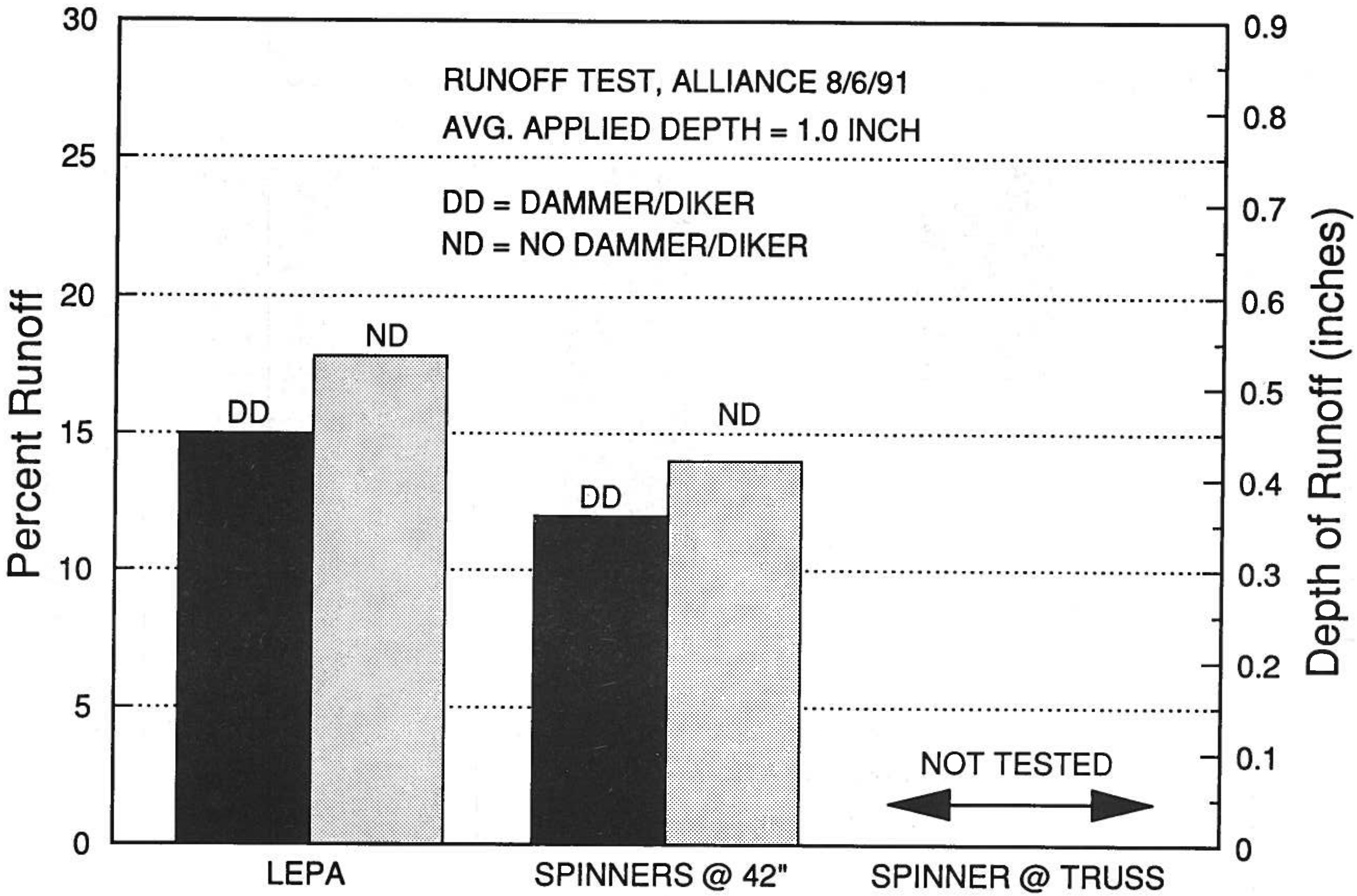

Figure 4. Percent runoff and depth of runoff for LEPA system and spinners at 42" height.

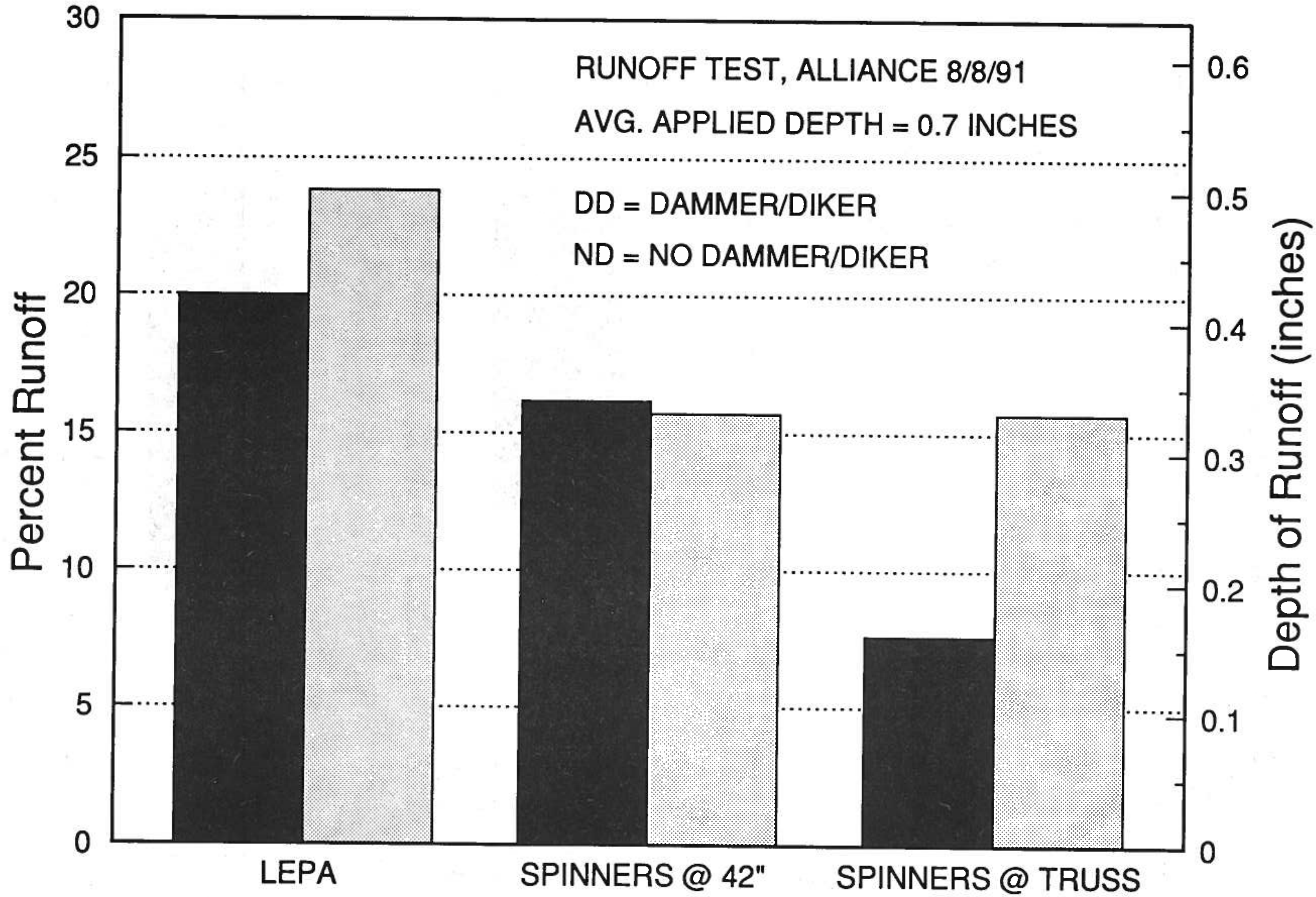

Figure 5. Percent runoff and depth of runoff for LEPA system, spinners at 42" height and spinners at truss rod height.