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UNIFORMITY OF IN-CANOPY CENTER PIVOT SPRINKLER IRRIGATION

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Summary:
Using center pivot sprinkler nozzles below the top of the corn crop canopy presents unique design and management considerations. Distortion of the sprinkler pattern can be large and the resultant corn yield can be reduced. Concepts are presented to help explain the different design and management considerations.

Keywords:
Sprinkler irrigation, LEPA, Spray nozzles, Irrigation management

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ABSTRACT

Using center pivot sprinkler nozzles below the top of the corn crop canopy presents unique design and management considerations. Distortion of the sprinkler pattern can be large and the resultant corn yield can be reduced. Concepts are presented to help explain the different design and management considerations.

INTRODUCTION

There is much interest in LEPA and in-canopy center pivot sprinkler irrigation. However, there are additional management and system design considerations whenever the sprinkler application pattern no longer results in a relatively uniform broadcast application.

This paper will primarily discuss from a conceptual approach, ideas such as symmetry of sprinkler application within the crop, spatial orientation of sprinklers with respect to crop canopy, and crop canopy sprinkler pattern distortions with respect to time-of-season. Symmetry of sprinkler application is when each plant or crop row has approximately equal opportunities for the irrigation water. An example of the concept of spatial orientation of sprinklers with respect to crop canopy might be the crop row orientation in relation to the direction of center pivot sprinkler travel. The importance of the time-of-season pattern distortion depends on whether the distortion occurs for the full season or whether it only occurs for a short period.

SYMMETRY OF SPRINKLER APPLICATION

Traditionally, sprinkler irrigation systems have been designed to uniformly apply water to the soil at a rate less than the soil intake rate to prevent runoff from occurring (Heermann and Kohl, 1983). These design guidelines need to be either followed or intentionally circumvented with appropriate design criteria when designing and managing a center pivot irrigation system using LEPA and other in-canopy sprinklers.

The importance of uniformity of water application and/or infiltration has been documented by numerous workers (Letey 1985; Seginer 1978; Seginer 1979; Duke et al. 1991; von Bernuth 1983; Feinerman et al. 1983; Zaslavsky and Buras 1967).

Seginer (1979) reported that an increase in uniformity can increase yields and decrease percolation. Duke et al. (1991) reported on several scenarios where improving the uniformity of center pivot sprinkler irrigation systems would be highly desirable from both an economic and environmental standpoint. Their results show irrigation non-uniformity such as overirrigation resulting in nutrient leaching or underirrigation resulting in water stress can cause significant economic reductions.

In some cases where irrigation is limited, a lower value of uniformity can be acceptable (von Bernuth, 1983). For example, if the maximum water application amount still falls upon the upward sloping line of the yield production function, a crop area deficient of water will be compensated for by an area receiving a larger amount of water (Figure 1). The example of nonuniform deficit irrigation has the same average application amount as the uniform irrigation amount. Overall production under the two systems would be identical because the production function is linear over the range of water applications.

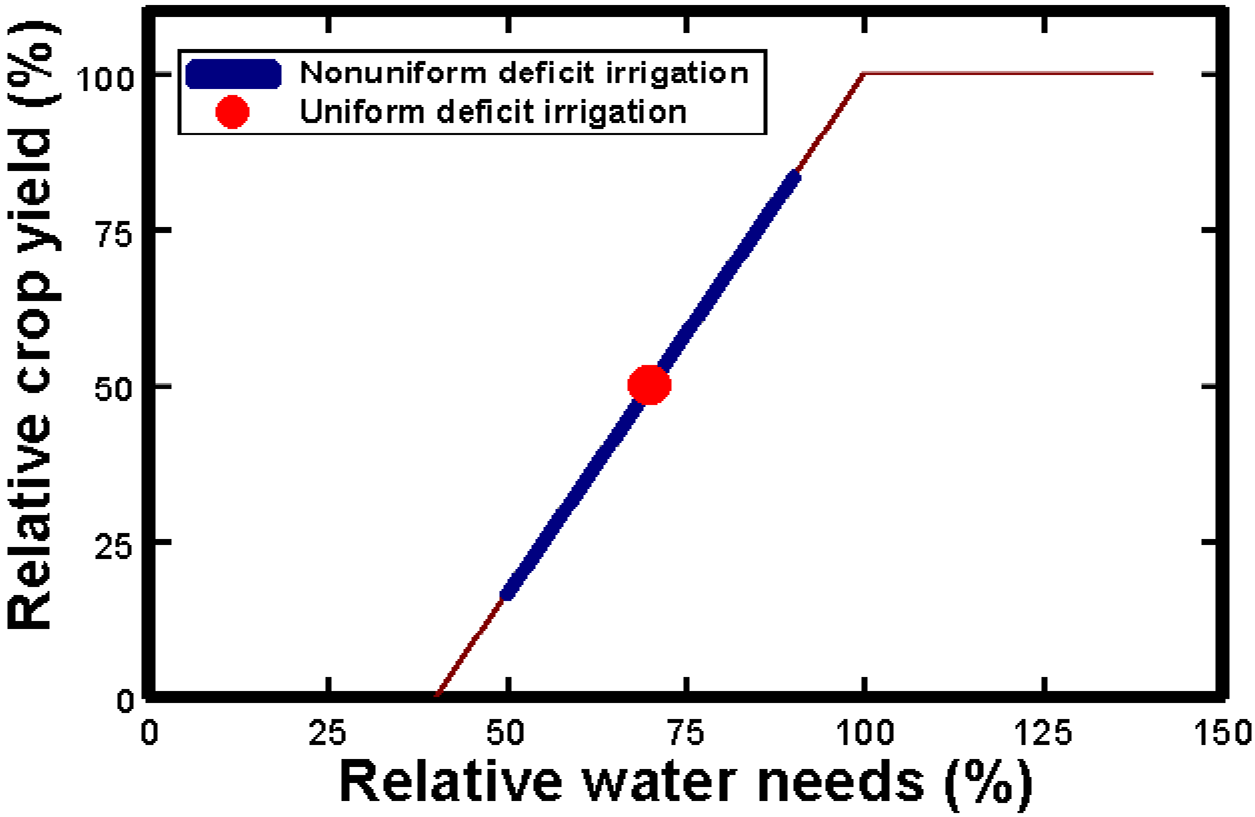

Figure 1. Hypothetical relationship of relative crop yield and relative water needs for non uniform deficit irrigation (bold range bar) and for uniform deficit irrigation (large dot). Average relative water need is the same for both irrigation schemes and consequently the average relative yield would also be the same.

The use of LEPA and other in-canopy sprinklers does not necessarily result in nonuniform application. In explaining the concept of the LEPA system, Lyle (1992) points out that one of the seven defining principles is that each plant should have an equal opportunity for water. Using the LEPA nozzle in the furrow between adjacent pairs of crop rows obeys this principle. Using a 1.5 m nozzle spacing with 0.75 m spaced crop rows planted circularly results in plants being approximately 0.38 m from the nearest sprinkler (Figure 2).

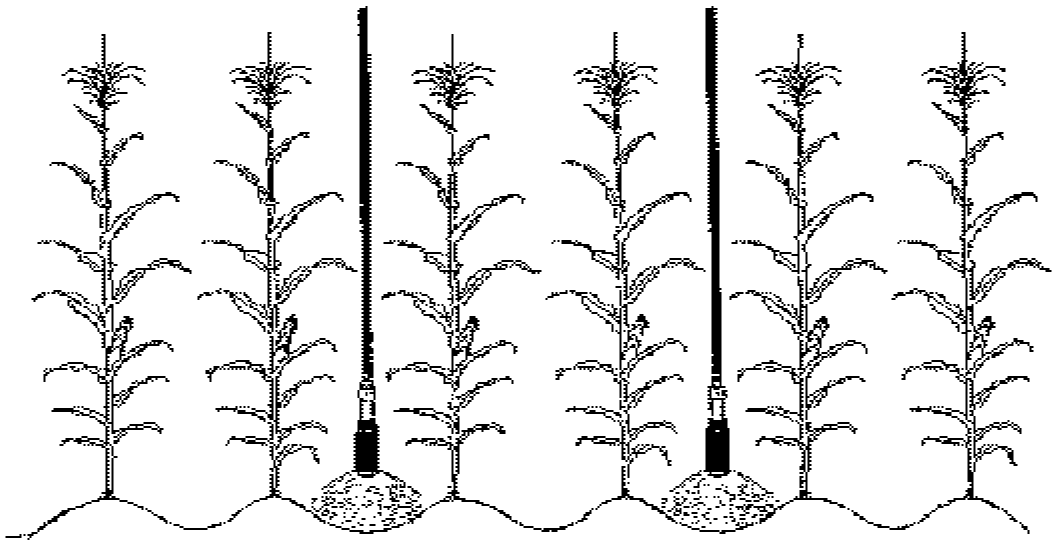

Figure 2. LEPA concept of equal opportunity for plants to applied water. LEPA nozzles are centered between adjacent pairs of corn rows.

Some irrigators are experimenting with wider in-canopy sprinkler spacings to reduce investment costs. In the Central Great Plains, some irrigators are trying 2.3, 3.0 and even 4.6 m in-canopy sprinkler spacings. Spray nozzles which perform adequately at these spacings above bare ground have a severely distorted pattern when operated within the canopy (Figure 3). Hart (1972) concluded from computer simulations that differences in irrigation water distribution occurring over a distance of approximately 1 m were probably of little consequence and would be evened out through soil water redistribution. Seginer (1979) noted that the overall effect on production of irrigation nonuniformity is related to the horizontal root zone of the crop. Figure 3 shows large differences in uniformity of irrigation application. These differences may or may not always translate into yield differences, but they should be considered in design.

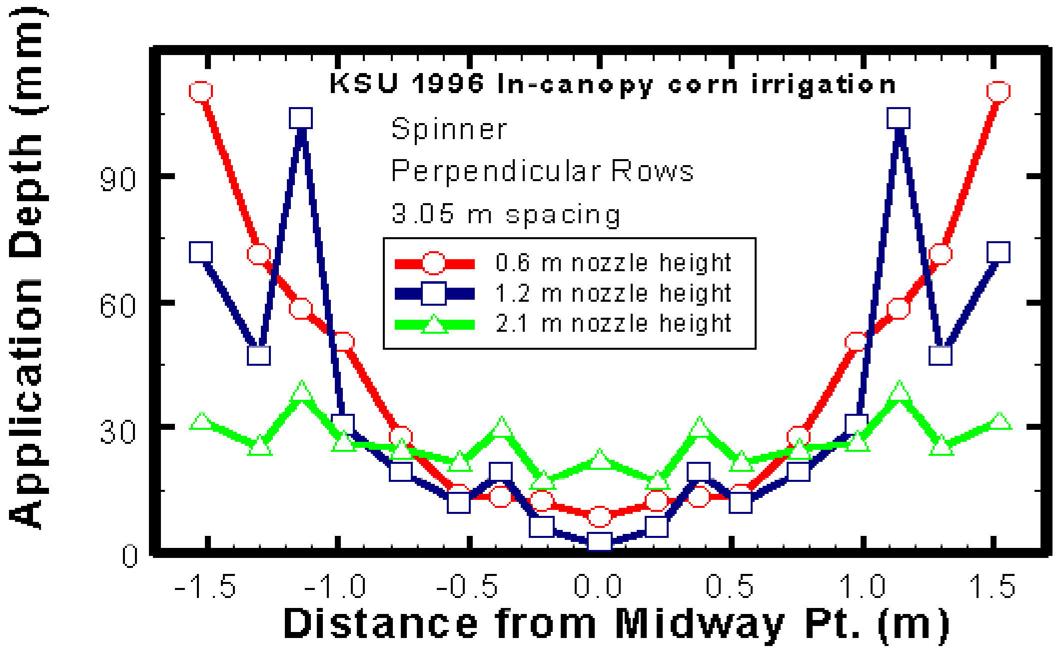

Figure 3. Differences in application amounts and application patterns that can occur when nozzle spacing is too wide for in-canopy application. Nozzles are located at right and left edge of each graphed line.

Distortion of the pattern will usually result in overwatering some areas which leads to runoff or deep percolation and underwatering in other areas which leads to crop yield reductions. Some irrigators in the Central Great Plains have tried to counter this argument by stating that their low capacity systems on nearly level fields restrict runoff to the general area of application. If this is so, using the concepts expressed by von Bernuth (1983), this non uniformity is probably acceptable. However, nearly every field has small changes in land slope and field depressions which do cause runoff if the irrigation application rate exceeds the soil infiltration rate. Another requirement of a true LEPA system is that there should be no runoff from the application point (Lyle 1992). In many cases this will require tillage management such as furrow dams.

SPATIAL ORIENTATION

The directionof travel of the center pivot sprinkler lateral with respect to crop row direction has added importance when in-canopy application is used. Generally, it has been recommended that irrigators plant rows circularly so that the rows are perpendicular to the sprinkler lateral. This satisfies two of the principles of LEPA irrigation noted by Lyle (1992): 1) be capable of conveying and discharging water into a single crop furrow; and 2) each plant has equal opportunity for irrigation water. In the Central Great Plains farmers have been reluctant to plant row crops such as corn in circular rows. Much of this reluctance is related to the concern about narrow or wide "guess" rows which cause cultivation and harvesting problems. However, using in-canopy sprinklers in non-circular planted rows can pose two problems (Figure 4). If the sprinkler lateral is perpendicular to the crop rows and the sprinkler spacing exceeds twice the crop row spacing, there will be nonuniform water distribution because of pattern distortion. If the sprinkler lateral is parallel to the crop rows there may be excessive runoff due to the large amount of water being applied in one or a few crop furrows. Differences in application amounts and patterns can be very large between the two crop row orientations (Figure 5).

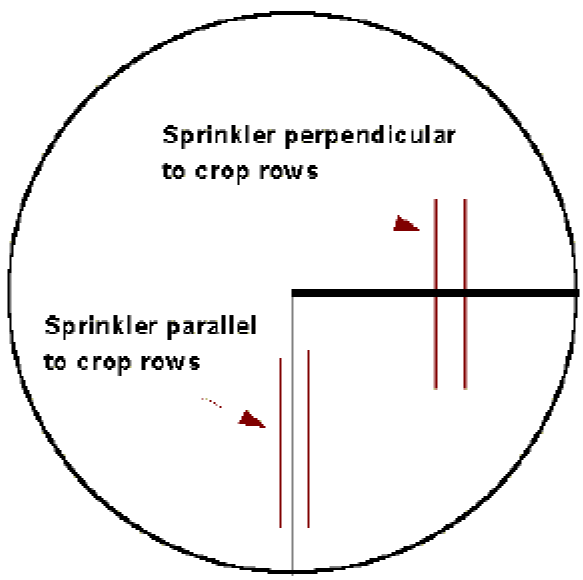

Figure 4. Two problematic orientations for in-canopy sprinklers in non-circular rows.

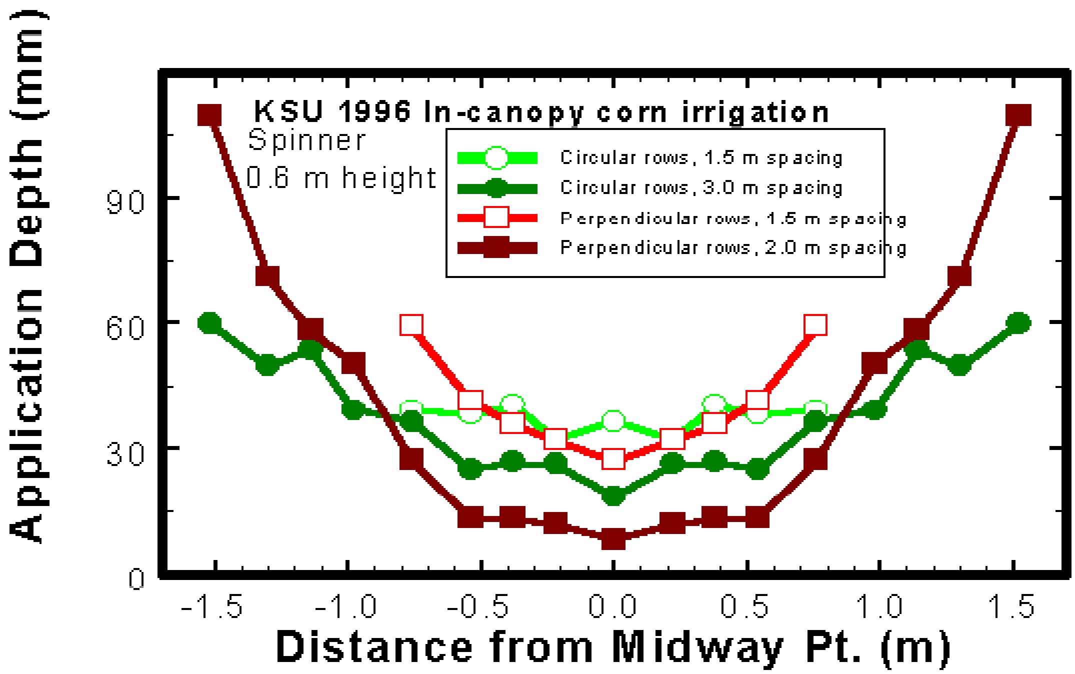

Figure 5. Differences in application patterns and amounts for in-canopy sprinklers in circular and non-circular rows.

PATTERN DISTORTION AND TIME OF SEASON

The duration and the time of season that sprinkler pattern distortion occurs significantly affect the performance of in-canopy irrigation.

It has been a common practice for several years in northwest Kansas to operate drop spray nozzles just below the center pivot truss rods. This results in the sprinkler pattern being distorted after corn tasseling. This has had relatively little negative effects on crop yields. The reasons are that there is a fair amount of pattern penetration around the tassels and because the distortion only occurs during the last 30-40 days of growth. In essence the irrigation season ends before severe deficits occur. Compare this situation with in-canopy sprinklers at a height of 0.45-0.60 m that may experience pattern distortion for more than 60 days of the irrigation season (Figure 6). If one assumes that a 50% pattern distortion might occur after tasseling, some corn rows would experience a 76 mm irrigation deficit. Assuming a 50%

distortion for the 0.45-0.60 m sprinklers beginning 30 days earlier would result in irrigation for some rows being 43% less than the needed amount. Yield reductions would be expected for the latter case because of the extended duration and severity. When the pattern is distorted and the nozzle spacing is wide enough to prevent some corn rows from getting equal opportunity to water, yields can be reduced (Figure 7.) Even though the average yield for both rows was high, there is a 3 Mg/ha yield difference between the row 38 cm from the nozzle and the corn row 114 cm from the nozzle for the 0.6 m nozzle height and 3 m nozzle spacing. There was slightly less row to row difference as the nozzle height is increased in 1997, as would be expected since pattern distortion was for a shorter period of time for the higher nozzle heights.

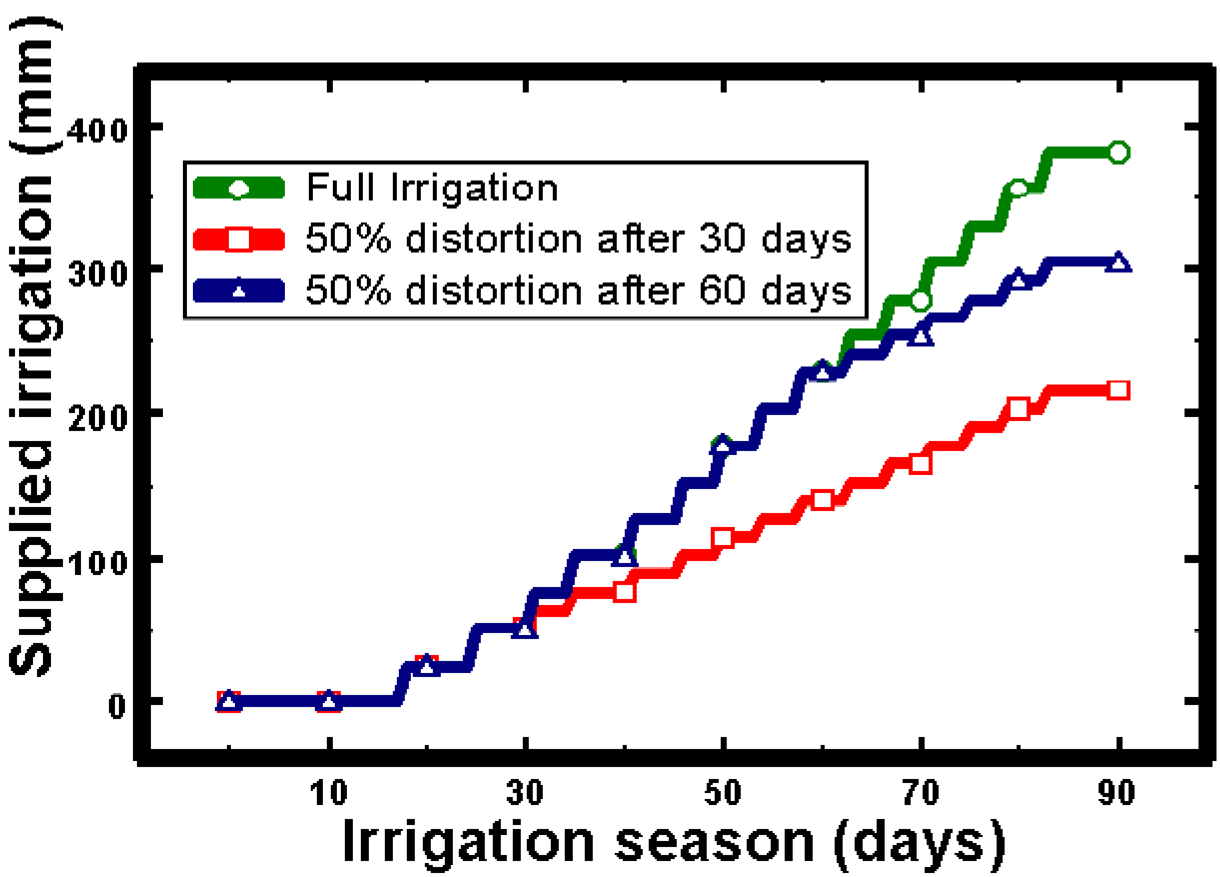

Figure 6. Hypothetical cumulative effect of 50% irrigation reductions for some corn crop rows as caused by in-canopy pattern distortions as related to time of occurrence, 30 or 60 days into the crop season at Colby Kansas.

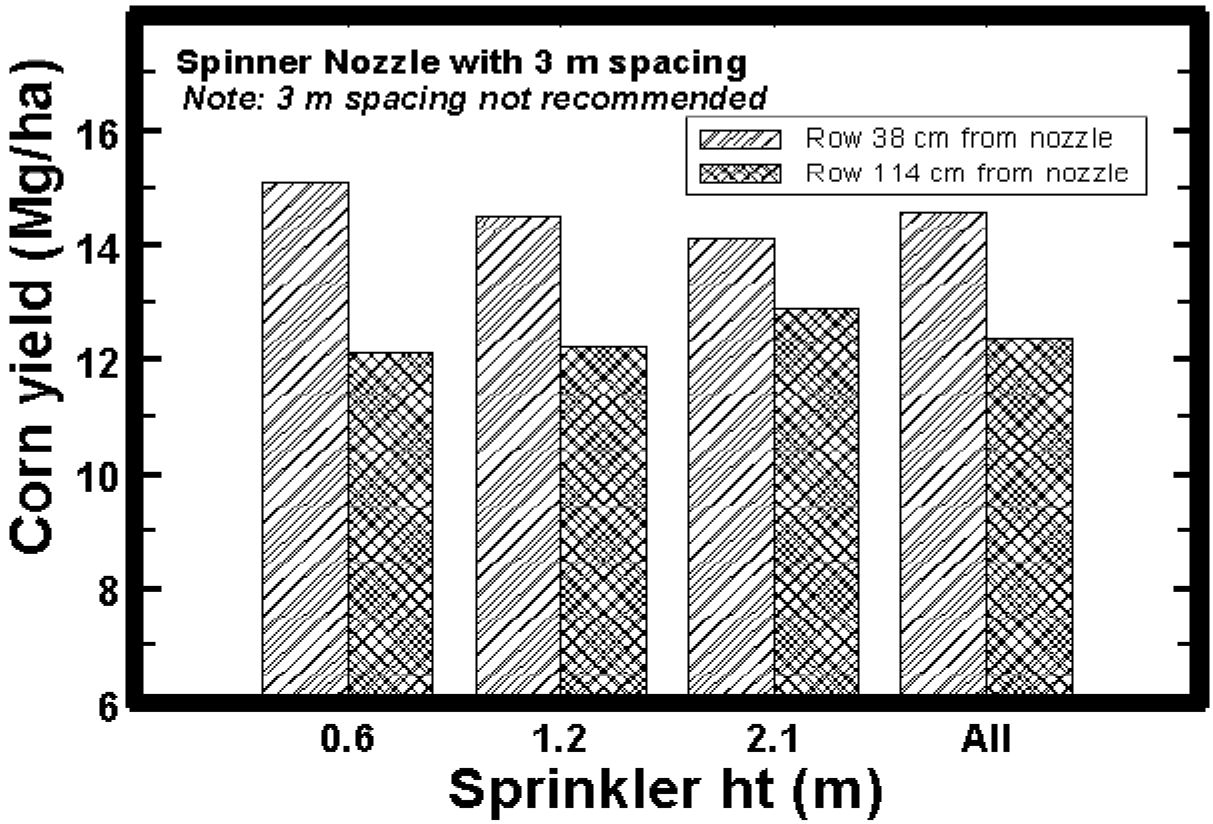

Figure 7. Row-to-row variations in corn yields as affected by sprinkler height for 3.0 m spaced in-canopy sprinklers. Data averaged across 4 irrigation levels. Data from 1997 sprinkler height study at Colby, Kansas.

CONCLUDING STATEMENTS

Most, if notall, of the concepts expressed in this paper are not new and many are intuitively obvious. However, there are still poorly designed and poorly managed in-canopy irrigation systems.It is the responsibility of irrigation professionals to remind irrigators that efficientand effective irrigation delivery starts with sound hardware design and ends with good management.

1 The mention of trade names or commercial products does not constitute their endorsement or recommendation by the authors or by the Kansas Agricultural Experiment Station.

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