ENSURING EQUAL OPPORTUNITY SPRINKLER IRRIGATION

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ABSTRACT

Equal opportunity to water applied by sprinkler irrigation to each plant must be carefully considered by crop producers, irrigation consultants, and the industry that supplies the irrigation equipment. Equal opportunity can be negated by improper marketing, design, and installation of equipment, as well as through improper farming operations, and irrigation mismanagement. These issues have greater significance when the irrigation is applied within or near the crop canopy. Key issues that must be addressed to ensure equal opportunity to sprinkler irrigation applications are irrigation application symmetry, spatial orientation of sprinkler travel with respect to crop rows, and the seasonal longevity of the sprinkler pattern distortion caused by crop canopy interference. There are both producer and industry roles in providing equal opportunity for the crop to the applied sprinkler water.

INTRODUCTION

Mechanical-move sprinkler irrigation systems are typically designed to uniformly apply water to the soil at a rate less than the soil intake rate to prevent runoff (Heermann and Kohl, 1983). In the U. S. Great Plains, there is a growing use of in-canopy and near-canopy sprinkler application because of reduced evaporative losses, however these application devices introduce a much greater potential for irrigation non-uniformity and run-off and/or run-on (i.e., surface redistribution). Some of the earliest descriptions of in-canopy sprinkler irrigation (Lyle, 1992) discuss the importance of all crop plants having equal opportunity to water, yet irrigators, designers and equipment manufacturers do not always follow this guideline. This paper will discuss the issue from a conceptual standpoint using both research and on-farm examples. The objective is attaining greater acceptance of this design criteria so that irrigator's can avoid the reduced crop production and runoff that occur when equal opportunity is violated.

SYMMETRY OF SPRINKLER APPLICATION

Uniformity of water application and/or infiltration is an important attribute in ensuring equal opportunity sprinkler irrigation (Zaslavsky and Buras, 1967; Seginer 1978; Seginer 1979, von Bernuth, 1983; Feinerman et al., 1983; Letey, 1985; Duke et al., 1991). Increased uniformity will often result in increased yields, decreased runoff, and decreased percolation (Seginer,1979). Improved sprinkler uniformity can be desirable from both economic and environmental standpoints (Duke et al., 1991). Their study shows irrigation non-uniformity can result in nutrient leaching from over-irrigation and water stress from under-irrigation. Both problems can cause significant economic reductions. Returning to the first sentence of this paragraph, the careful wording can be noted of “uniformity of water application and/or infiltration”. This wording suggests that the primary goal is for the plants to have equal opportunity to root-zone soil water.

Sprinkler irrigation does not necessarily have to be a uniform broadcast application to result in each plant having equal opportunity to the irrigation water. Equal opportunity can still be ensured using a low energy precision application (LEPA) nozzle in the furrow between adjacent pairs of crop rows provided runoff is controlled (Figure 1).

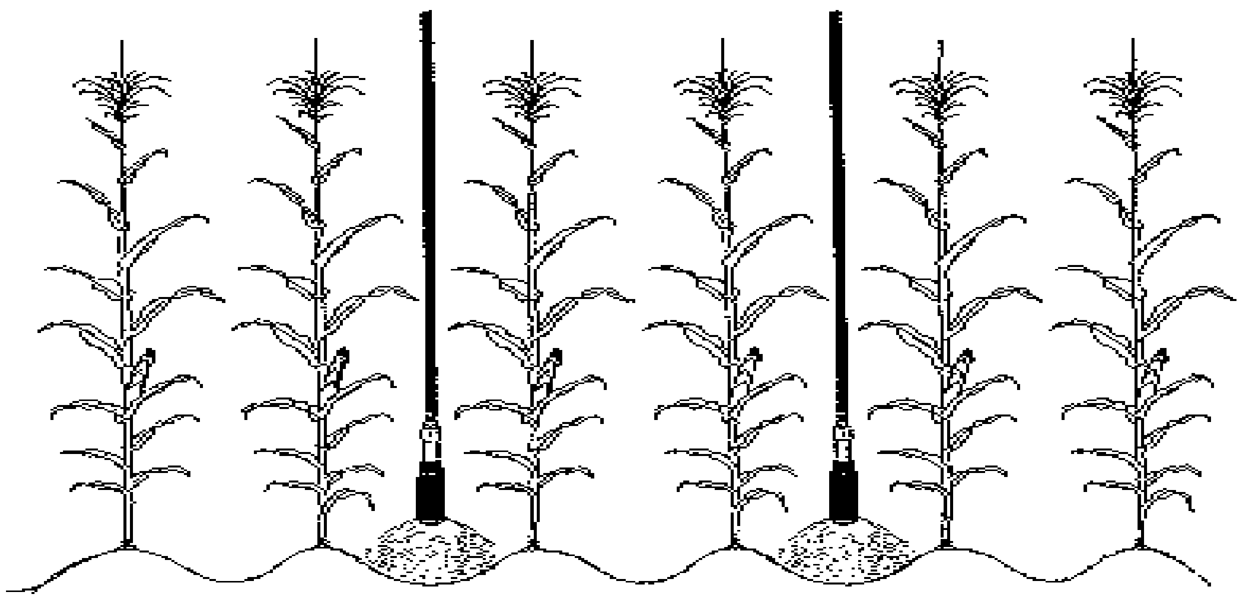

Figure 1. LEPA concept of equal opportunity of plants to applied water. LEPA heads are centered between adjacent pairs of corn rows. Using a 5–ft nozzle spacing with 30-inch spaced crop rows planted circularly results in plants being approximately 15 inches from the nearest sprinkler. After Lamm (1998).

Some sprinkler application non-uniformity can also be tolerated when the crop has an intensive root system (Seginer, 1979). When the crop has an extensive root system, the effective uniformity experienced by the crop can be high even though the actual resulting irrigation system uniformity within the soil may be quite low. Additionally, when irrigation is deficit or limited, a lower value of application uniformity can be acceptable in some cases (von Bernuth, 1983) as long as the crop economic yield threshold is met.

Some irrigators in the U. S. Great Plains are using wider in-canopy sprinkler spacings (e.g., 7.5, 10, 12.5 and even 15 ft) in an attempt to reduce investment costs (Yonts et al., 2005). Spray heads which perform adequately at a 10 ft interval above bare ground have a severely distorted pattern when operated within the canopy (Figure 2).

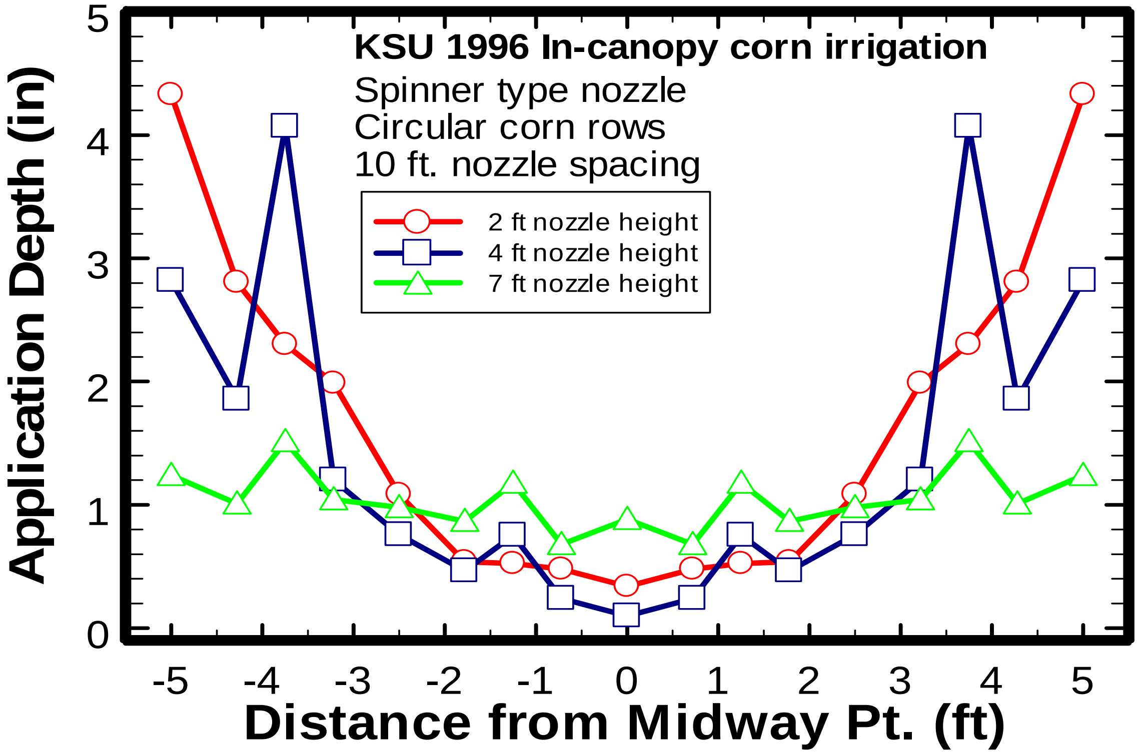

Figure 2. Differences in application amounts and application patterns as affected by sprinkler height that can occur when sprinkler spacing is too wide (10 ft) for in-canopy application. Center pivot sprinkler lateral is traversing parallel to the circular corn rows. Data are from a fully developed corn canopy, July 1996, KSU Northwest Research-Extension Center, Colby, KS. Data are mirrored about the centerline for display purposes.

Although Figure 2 indicates large application non-uniformity, these differences may or may not always result in crop yield differences, but they should be considered in design. Hart (1972) concluded from computer simulations that differences in irrigation water distribution occurring over a distance of approximately 3 ft were probably of little overall consequence and would be evened out through soil water redistribution. Some irrigators in the Central Great Plains contend that their low capacity systems on nearly level fields restrict runoff to the general area of application. However, nearly every field has small changes in land slope and field depressions which do cause field runoff or percolation when the irrigation application rate exceeds the soil infiltration rate. In the extreme drought years of 2000 to 2003 that occurred in the U. S. Central Great Plains, even small amounts of surface water movement affected sprinkler-irrigated corn production (Figure 3).

Figure 3. Large differences in corn plant height and ear size for in-canopy sprinkler application over a short 10-ft. distance (4 crop rows) as caused by small field microrelief differences and the resulting surface water movement during an extreme drought year, Colby, Kansas, 2002. The upper stalk and leaves have been removed to emphasize the ear height and size differences.

Mechanical-move sprinkler system manufacturers do not always provide nozzle spacings that ensure equal opportunity to the water. There are a host of nozzle outlet spacings available from industry, 30, 57, 90, 108 inches and the multiples of these spacings, but often a particular manufacturer will have their own limited selection which may be further limited in some span lengths. The industry may have valid reasons for this limitation related to overall inventory and international marketing but that does little to accommodate the various crop row spacings (e.g., 30, 36, 38, 40 inches, etc.) that are commonly used in the United States. Since irrigation is primarily a tool to increase crop production, maybe ensuring equal opportunity to the sprinkler irrigation water should be more important than marketing issues. After market suppliers have provided some solutions to this problem through furrow-arm goosenecks and hose draping devices but these “fixes” can be cumbersome to adjust and maintain in the proper position.

SPATIAL ORIENTATION

The direction of travel of the mechanical-move sprinkler lateral with respect to crop row direction can affect the equal opportunity issue when in-canopy application is used. It has been recommended for center pivot sprinkler systems that crop rows be planted circularly so that the rows are perpendicular to the sprinkler lateral. Matching the direction of travel to the row orientation satisfies the important LEPA Principles 2 and 5 noted by Lyle (1992) concerning water delivery to one individual crop furrow and equal opportunity to water by for all plants.

Some producers have been reluctant to plant row crops in circular rows because of the cultivation and harvesting difficulties of narrow or wide "guess" rows. However, using in-canopy application for center pivot sprinkler systems in non-circular crop rows can pose two additional problems (Figure 4). In cases where the CP lateral is perpendicular to the crop rows and the sprinkler spacing exceeds twice the crop row spacing, there will be non-uniform water distribution because of pattern distortion. When the CP lateral is parallel to the crop rows there may be excessive runoff due to the great amount of water being applied in just one or a few crop furrows. There can be great differences in in-canopy application amounts and patterns between the two crop row orientations (Figure 5).

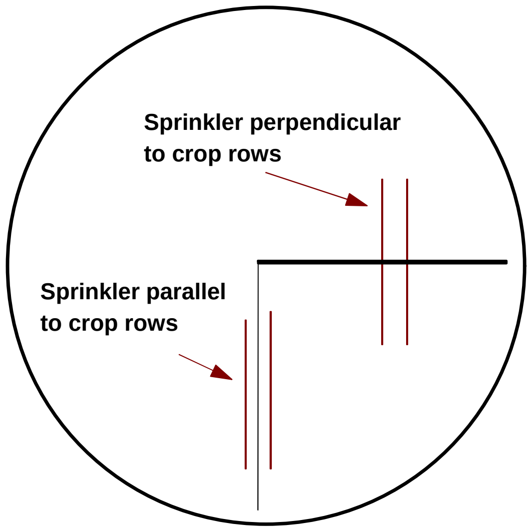

Figure 4. Two problematic orientations for in-canopy sprinklers in non-circular rows.

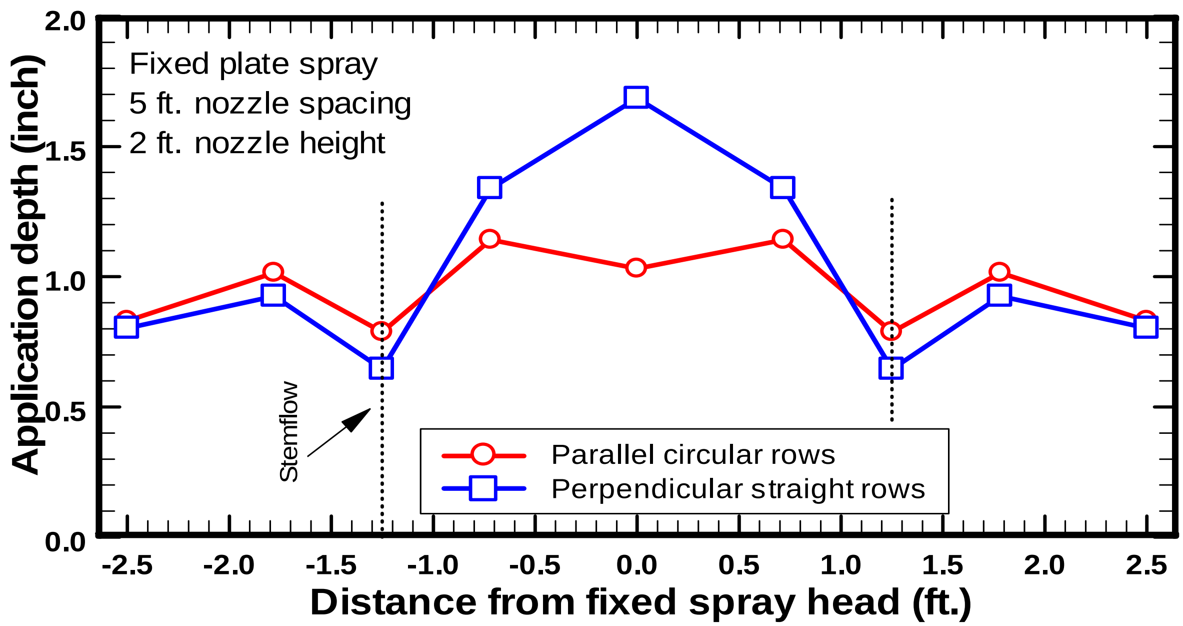

Figure 5. Differences in application amounts and application patterns as affected by corn row orientation to the center pivot sprinkler lateral travel direction. Dotted lines indicate location of corn rows and stemflow measurements. Data are from a fully developed corn canopy, July 23-24, 1998, KSU Northwest Research-Extension Center, Colby, KS. Data are mirrored about the centerline.

PATTERN DISTORTION AND TIME OF SEASON

Drop spray nozzles just below the center pivot sprinkler lateral truss rods (approximately 7-8 ft height above the ground) have been used for over 25 years in northwest Kansas. This configuration rarely has had negative effects on crop yields although the irrigation pattern is distorted after corn tasseling. The reasons are that there is only a small amount of pattern distortion by the tassels and this distortion only occurs during the last 30 to 40 days of growth. In essence, the irrigation season ends before a severe soil water deficit occurs. Compare this situation with spray heads at a height of 1 to 2 ft that may experience pattern distortion for more than 60 days of the irrigation season. Yield reductions might be expected for some corn rows in the latter case because of the extended duration of the pattern distortion. Lowering an acceptably spaced (10 ft) spinner head from 7 ft further into the crop canopy (e.g., 4 or 2 ft) can cause significant row-to-row differences in corn yields (Figure 6).

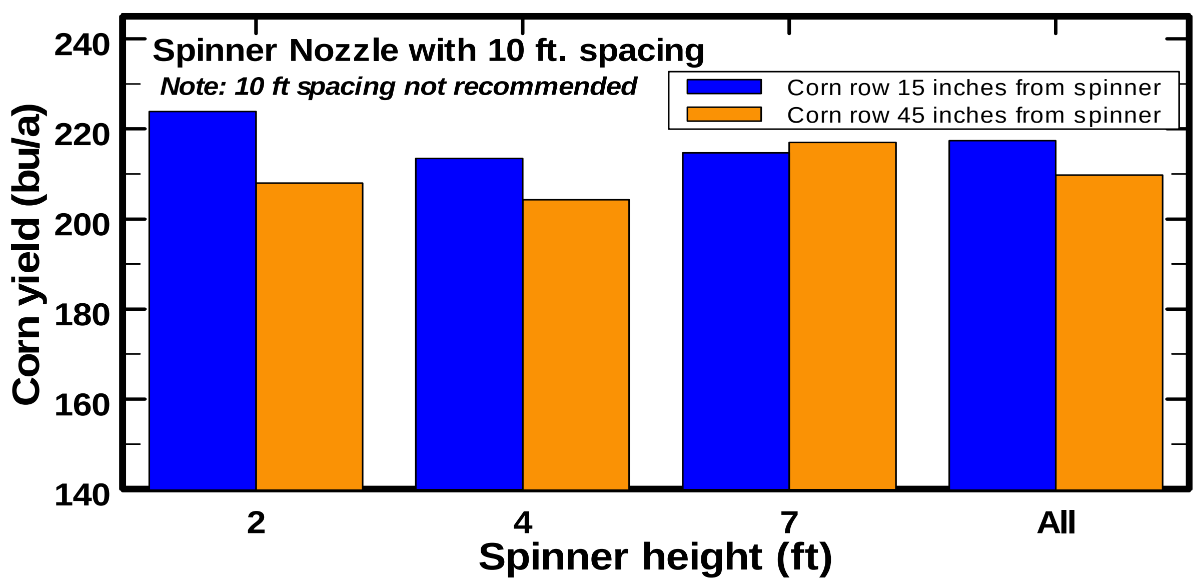

Figure 6. Row-to-row variations in corn yields as affected by sprinkler height for 10 ft. spaced in-canopy sprinklers. Sprinkler lateral travel direction was parallel to crop rows. Data was averaged from four irrigation levels for 1996 to 2001, KSU Northwest Research-Extension Center, Colby, KS.

CONCLUDING STATEMENTS

Short and long term water supply problems in the U. S. have forced those involved with irrigation to look for cost-effective, water saving techniques. Sprinkler irrigation is now the predominant irrigation method in the U. S. Great Plains because of both water and labor savings. Ensuring equal opportunity of crop plants to the applied water has long been recognized as an important tenet of irrigation, yet there continues to be a lack of appropriate attention to this rule particularly with the newer in-canopy and near-canopy sprinkler application techniques. Both end-users and industry have important roles in solving this problem. Neglecting this equal opportunity issue can easily waste more water and cause more crop yield reductions than other irrigation problems producers and industry are trying to avoid.

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